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Instruments

THE MAGAZINE OF *Measurement and Control*

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INCLUDING *Aviation Instruments*

BAROMETERS
Mercurial

CONTROLLERS
Flow
Humidity
pH
Liquid Level
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Temperature
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Pressure
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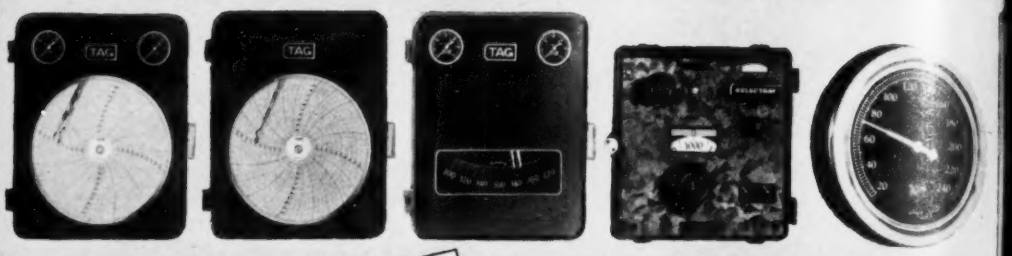

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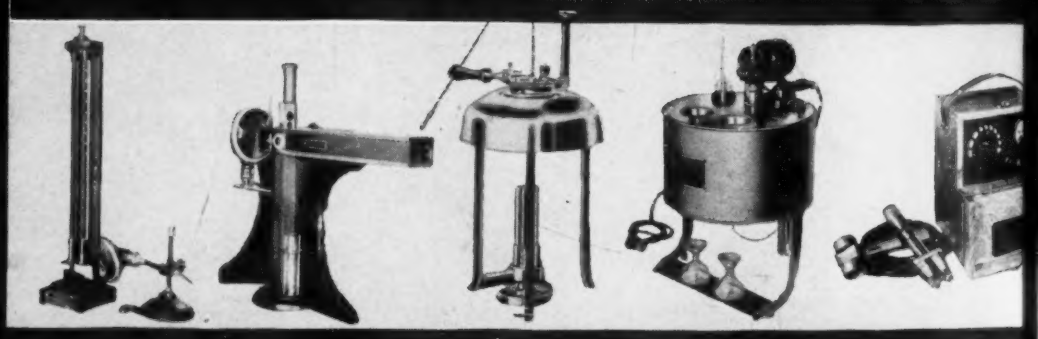

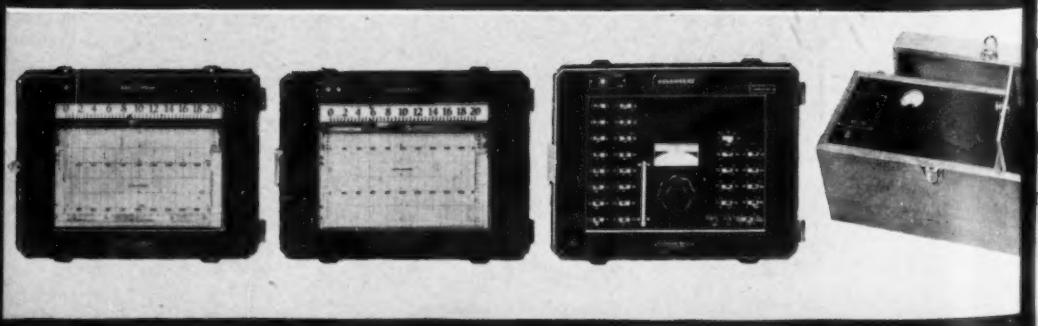

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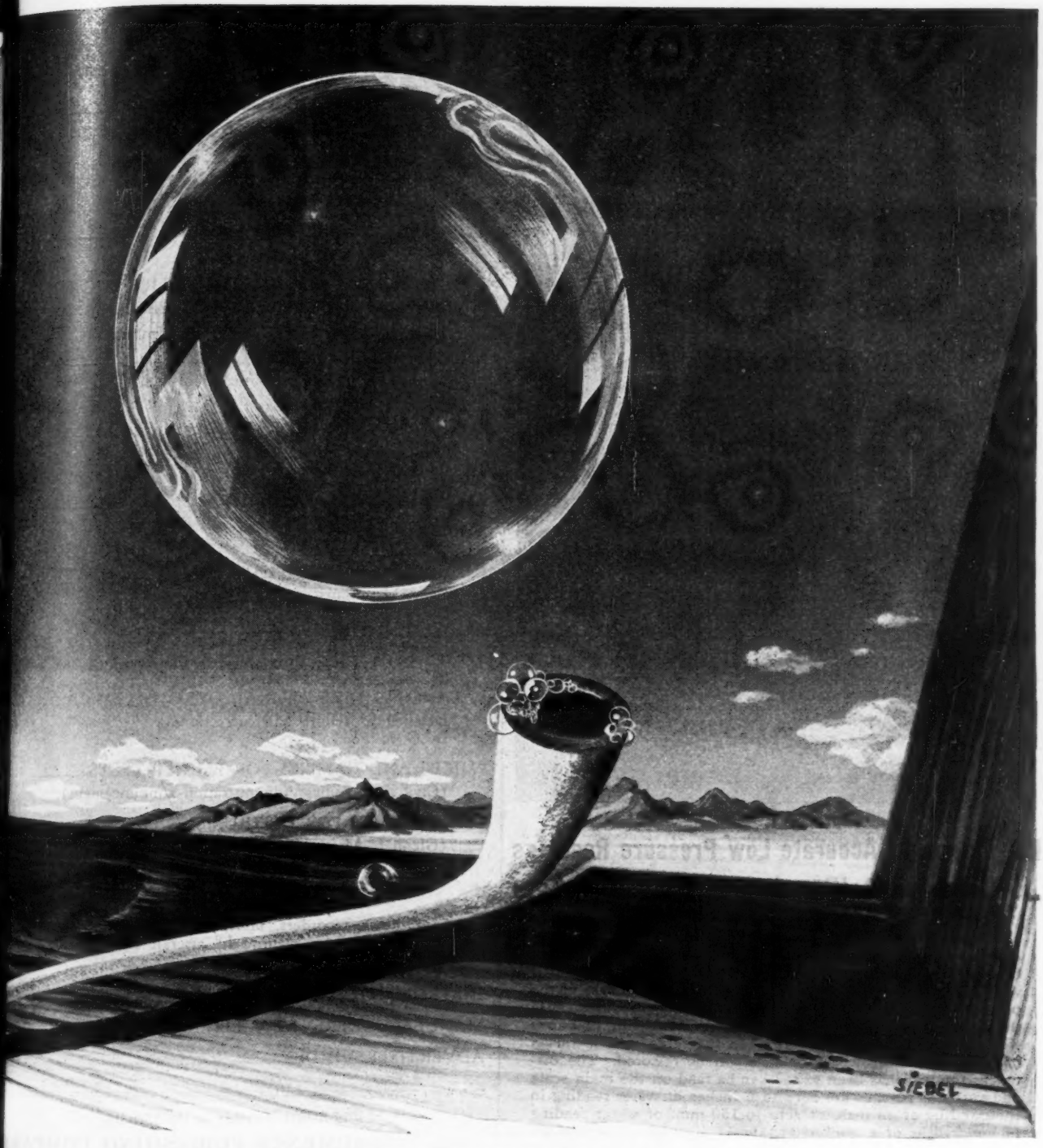

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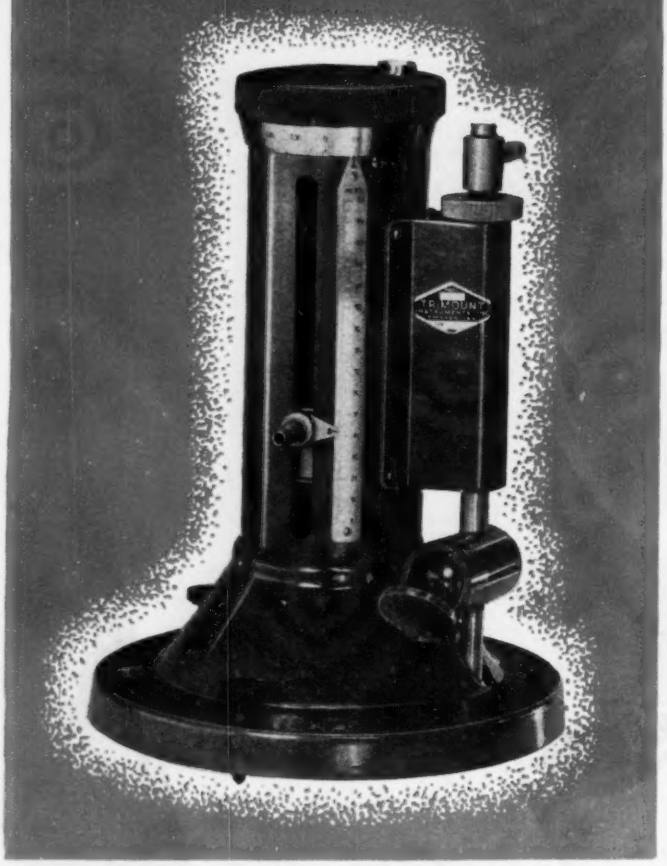

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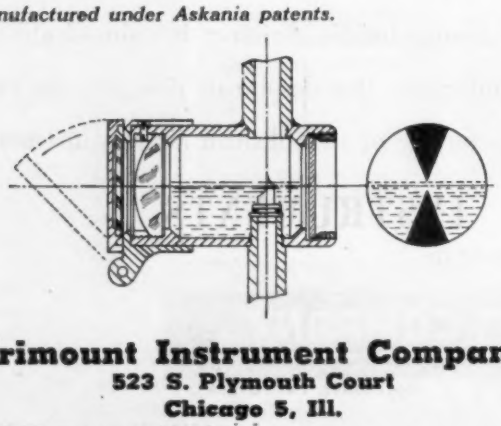

Trimount Instrument Company
523 S. Plymouth Court
Chicago 5, Ill.

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

HOME-FRONT HERO

1894 John Swauger 1944

ENGINEER SOLDIER
INSTRUMENTICIAN

SOME magazines displayed Old Glory on the covers of their July 1942 issues and most of them (including *Instruments*) did so in 1943. This year the theme suggested by the Treasury Department is a $100 Series E war bond—alone or superposed on a suitable background.

Our cover subject for July
Does not include the picture of a bond.
I have already made a choice; rather, I had no choice:
The picture chose itself before my faithful eye
As if by higher Will than that of mortal man
A day or two after we laid to final rest
With sound of Taps and rifle volleys three
Beside his forebears in the town where he was born
The weary body of the home-front hero
Whose life shall be my theme this month.
Of all the moments in his laudable career
The one the camera caught two years ago
Exemplifies his panoply of skill, of leadership,
Of steadfast love of native land.
No war-bond picture need be superposed
On this the picture thus ordained for *Instruments;*
No added feature could enhance
Its inspiration.

BARE FACTS ABOUT COVER PICTURE.—*Time:* May 1942. *Place:* Westinghouse plant. *Occasion:* visit by AAF's first ace, Capt. Hewitt T. Wheless (second from left) accompanied by Lt. Col. C. W. Kerwood (right), received by Westinghouse Vice-pres. A. C. Streamer (left) and escorted by Pittsburgh Ordnance District's Industrial Div. Chief, Lt. Col. John S. Swauger (second from right), who had been General Inspector at Westinghouse before going on active duty in the Army on Jan. 1, 1940. *Incident caught by camera:* Lt. Col. Swauger recognizes and shows a height gage with J. S. SWAUGER stamped on base.

Significance: Swauger had designed and built this gage (and others) twenty-five years before, when he made special tools and instruments for Westinghouse during World War I. Today this 27-year-old gage is as good as new.

From obituaries: " . . . born July 9, 1894, West Newton, Pa., son of James Pepple Swauger and Margaret (Frey) Swauger . . . "

Some thirty miles south-east of roaring clanking Pittsburgh, the little town of West Newton has nestled in a scenic river valley for a hundred years of blessed peace: diversified farms, small factories, schools, churches, lodges, literary clubs. . . . To his dying day John remained simple, direct. Some said he was naïve; I say he was straight-thinking and plain-speaking. To understand his simple kind of patriotism you must understand that he always *lived* (though in recent years he did not *reside*) in this grass-roots town of *united* Americans.

From company records.—In 1912, on graduating from West Newton High School, he went to work in a nearby plant of U.S. Radiator Corp. as "tool and pattern maker and mechanical draftsman." In 1916, "toolmaker" for the old Westinghouse Machine Co. (which was merged into W.E.&M.Co. in 1917). 1919-20 "tool designer," '20-24, "machine designer," '24-26 "demonstrator," '26-28 "Supervisor of Demonstrators," '28-33 'General Inspector." Transferred 1934 to Westinghouse Micarta Works as "Division Staff Supervisor." Jan. 1, 1940: on leave to Armed Forces.

When John went to work at 17 he began taking ICS courses and kept on for many years. At 18 he married his boyhood sweetheart Katherine Weaver. They reared three sons (all in the Infantry today) and one daughter (in war work today) but John studied his ICS lessons while rocking his children to sleep, until he mastered calculus and advanced engineering subjects.

From obituaries: " . . . Senior Member American Society of Tool Engineers, Member American Society of Mechanical Engineers, Member Army Ordnance Association, Honorary Member Harvard-Yale-Princeton Club of Pittsburgh, Past-President Rotary Club of Turtle Creek, Pa. . . . "

Years of teaching developed Swauger's ability as a public speaker. In recent years, however, it was not his technique, but his heart and soul, that made him be in demand as toastmaster and principal speaker. Scorning ghost-writers, he spent midnight hours in painstaking preparation. He stirred his visible audiences deeply; and even radio audiences listened to the end. One of his Army-Navy "E" presentations has been recorded by Station KDKA and, if any of you chance to hear it the tears will come to your eyes, for you will sense that a patriot is working himself to a premature death.

From Army records.—Entered Ordnance Reserve Aug. '29 as 1st Lt.; April '34 com. Capt.; Aug. '40 com. Major; Feb. '42 com. Lt.-Col. Active service: several 2-week summer training courses bet. 1929 and 1939; continuous from Jan. 1 '40 to day of death May 25, '44. Assignments Pittsburgh Ordnance District Office: Chief Metal Components Sec., charge of gage procurement plans; July '40 apptd Ass't Exec. Officer, Chief Industrial Div.; Dec. '40 Exec. Officer Pittsburgh District. Several sick leaves '42, '43 and '44. Died of a heart attack May 25 '44.

The real beginnings of Swauger's military career are not in published records, for he was a civilian agent of Army Intelligence during World War I.

Shortly after I came to Pittsburgh and served on various officers' training and examining boards, I saw how he stood out among the other junior officers: most of them were graduates of colleges and engineering schools, most of them were superior types of men, but none outshone him as an engineer or as a leader of men, none equalled him in patriotic devotion and understanding.

Astronomical instruments had made us friends some years before, when each discovered that the other had in boyhood designed and built a telescope and equatorial mounting. The Army gage procurement program had also strengthened our ties: John's vision went beyond mine in making Pittsburgh rival New England in the finest precision work. We also had a common interest in instrumentation for automatic inspection, a field in which his personality and his knowledge of shop men accomplished far more than did all my missionary work among the engineer-type men. When the war is won, the Army will no doubt reveal in full the many ways in which John Swauger helped win it through Instrumentation.

—MFB

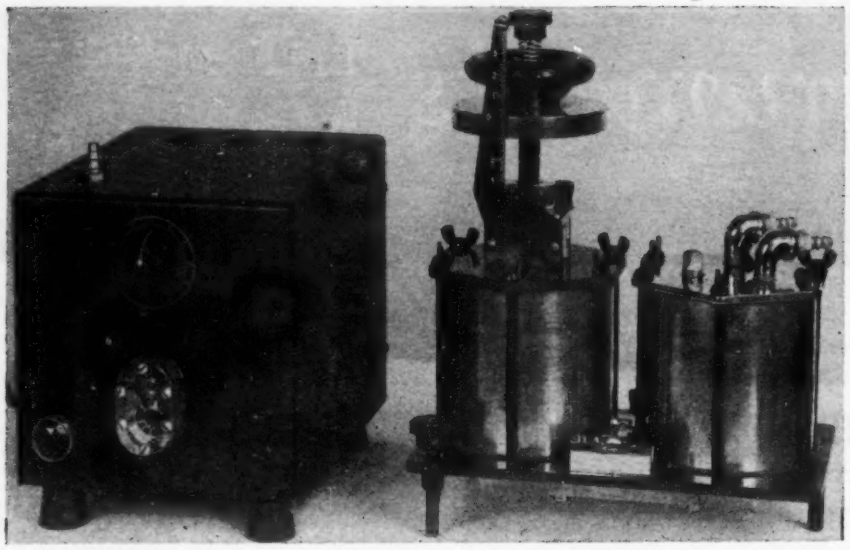

Fig. 1. Complete manometer, micrometer screw and dial, pump and pump control box assembled.

An Automatically-controlled Calibrating Standard for Low Pressures (to 3″ water column)

By DON BURNS, Research and Development Engineer, The Hays Corporation, Michigan City, Indiana

DURING the development and subsequent manufacture of a sensitive air flow meter, which measures flows of gases at 0.5″ water column maximum differential, it was found necessary to supplant the previously-used methods of calibration with an "automatic" standard which would create and maintain calibrating pressures up to 3″ of water.

Accuracies on the calibrating standard of ±0.0005″ water were desired. This required a sensitivity of the order of 0.00005″ or better, since some error must be contemplated in the other mechanical parts of the instruments.

A single setting, preferably on a micrometer screw and attached dial, was essential in order to make the calibrated scale long enough to minimize human error in the setting or reading of the pressure.

A "primary" type of measuring instrument, wherein only a distance and the density of a standard liquid are involved in the pressure measurement, was indicated, which in turn called for a water manometer having the "legs" sufficiently large in area to prevent surface tension and adhesion from appreciably influencing the readings. Tubes four inches in diameter met this requirement.

Since a single reading on a U-tube manometer was to be used and the micrometer screw was to have a standard thread, the two legs must be of exactly the same area in order to make the increase in level on one side equal the decrease in level in the other side. This requirement made glass tubing excessively expensive and practically prohibited its use.

A major problem was to make the micrometer screw measure the level of the water accurately. Since metal tubing was to be used, visual means of measurement were rejected, particularly since the allowable error was so small and since the automatic maintenance of pressure was desired.

Electrical contact between the water and a point mounted on the micrometer screw was unsatisfactory because it could only be serviceable when the water is rising and approaching the dry point: when the general level is dropping, surface tension keeps the local level up to the now-wetted contact point —several thousandths of an inch higher than the general level—before the contact is finally released, and then a droplet of water may be held on the point to make an erroneous reading the next and succeeding times the water approaches the point.

Another means considered was to use a plate whose plane is normal to the axis of the micrometer screw and parallel to the water surface; and to measure the capacitance through suitable means. This arrangement may be used if one is careful not to "dunk" the plate,

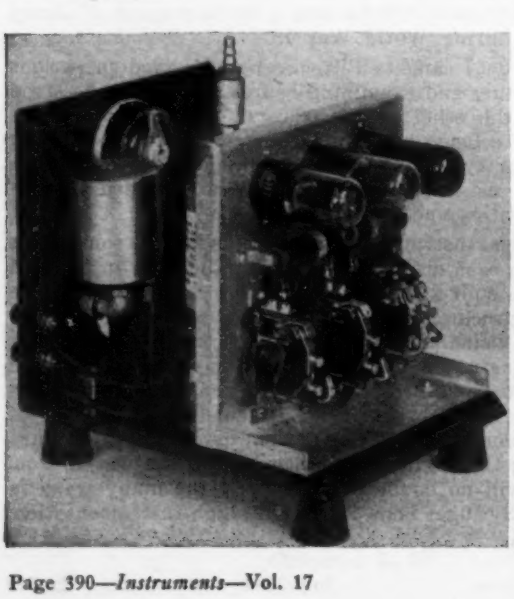

Fig. 2. Pump control, cover removed showing electronic relays, "slow speed" control rheostat and separating chambers.

Fig. 3. Manometer disassembled, showing micrometer screw, zero screw, honed tube and float with guide funnel.

as here again droplets of water may be left on the plate to vitiate the reading. It may be suitable in a research laboratory but the possibility of interrupted work precluded its adoption for our purpose which is related to war production.

A sharp rise in current or voltage with an extremely small movement of the level was needed if a relay was to operate reliably within the specified limits. Therefore, a spun copper float, with a rounded contact inside at water level, floating on the water in the measuring side of the manometer, together with a flat contact whose plane was normal to the axis of the screw to form the contact parts, suited the need very well. An insulated guide funnel, into which the flat contact on the micrometer screw fits loosely, provided a minimum-friction guide for both the contact junction and the float.

This arrangement allows a minimum of level change to make or break the contact. The contacts do not chatter because the water has enough inertia to make and break the contacts cleanly when operated with the pump.

Since distilled water was to be used and it was desirable to prevent the contacts from burning or pitting, the current passed by the contacts was limited. Therefore, an electronic relay was used in conjunction with an electromagnetic relay to obtain suitable output to operate other devices. For safety reasons the voltage across the contacts, when open, was likewise made low. The current on the contacts is about 0.5 microamp. and the voltage, when the contacts are open, about 25 volts. Although the current could have been further reduced, it was found impractical and unnecessary to build the instrument with the high insulation resistance that would have been required to make it operate reliably on such low power levels.

The micrometer screw was made 20 threads to the inch in order to obtain 100 "one-thousandth" inch marks per turn. The dial is about 4.75" in diameter, making the length of scale about 150" per inch of pressure. The dial may be set and read to 0.0002" quite easily. The screw is made of steel and has a penetrated finish to prevent rust. The nut is self-adjusting by spring tension and is made of brass to minimize screw wear. Both the screw and the nut were cut on a precision lathe and test showed that they compared favorably with a precision micrometer. The micrometer screw was drilled and tapped for a zero screw to eliminate the necessity of subtracting a zero reading.

The tubes or "legs" of the manometer were honed in tandem on a cylinder honing machine. Although quite difficult to measure, they were found to be within 0.0002" in diameter at all points and their cylindricality is likewise "true."

The unit was so designed that it can be disassembled for cleaning and checking. It is also made with the idea in mind that some day a set of glass tubes may be obtained and substituted for the metal, primarily to enhance the appearance and satisfy a desire to see it work.

The pump used is a small reversible gear pump, oil-sealed, having a capacity of about seven cubic inches per minute. Its driving motor is variable-speed over a range of about 8 to 1.

Since extreme sensitivity is required, any differential or dead zone would not only make a troublesome adjustment but would detract from the sensitivity. Therefore, the pump control circuit is so designed that when the contact in the manometer is made, the pump runs to decrease the pressure at the manometer and, when the contact is opened, the pump reverses to increase the pressure. Thus the pump "hunts" or reverses continually and, in that sense, there is no dead zone.

At full speed, the reversing pulsations of the motor-driven pump are felt by the instrument under calibration, but at slow speed these pulsations are minimized until they are no longer noticeable. Therefore, a second circuit was incorporated into the pump control unit which would make the pump run slowly when the setting point is reached and speed up between calibration points, thereby saving calibration time. This second circuit involves an electronic time delay relay which resets when the pump reverses.

The amplitude of the pump-reversal pulsations, as indicated on the gage being calibrated, is inversely proportional to the gage capacity or the quantity of air required to fill its measuring element per unit deflection. Thus, when calibrating a small-bore manometer, the pulsations are very noticeable unless the pump runs slowly. Conversely, when calibrating a gage having a large diaphragm as a measuring element, the pump pulsations, even at fairly high pump speeds, are hardly noticeable. Their amplitude should never exceed the sensitivity of the gage being calibrated and should be appreciably less in most cases.

A piece of transparent plastic covers the pump gears and extends through the pump and control case. By watching the distance the gears travel or "creep," it is possible for the operator to tell whether the system, including the device being calibrated, has a leak or not.

The pilot light at the lower left of the pump and control panel indicates whether the contact within the instrument is open or closed.

The knob at the top of the pump and control panel is used for governing the "slow speed" and is only effective when the pump is reversing and holding the set pressure. As mentioned above, between set pressures the pump runs at full speed.

Although this particular unit was built for three inches suction or pressure, others have now been built for higher and lower values, the micrometer screw and lengths of tubes being the major change.

Further development will probably include a motor-driven micrometer screw and dial for taking automatic readings and a differential pressure measuring instrument so that measurements may be made under static pressures.

The development has been interesting not only from the accuracy, sensitivity, and sensitiveness standpoints but from the fact that electronic means made the instrument possible and solved many of its problems.

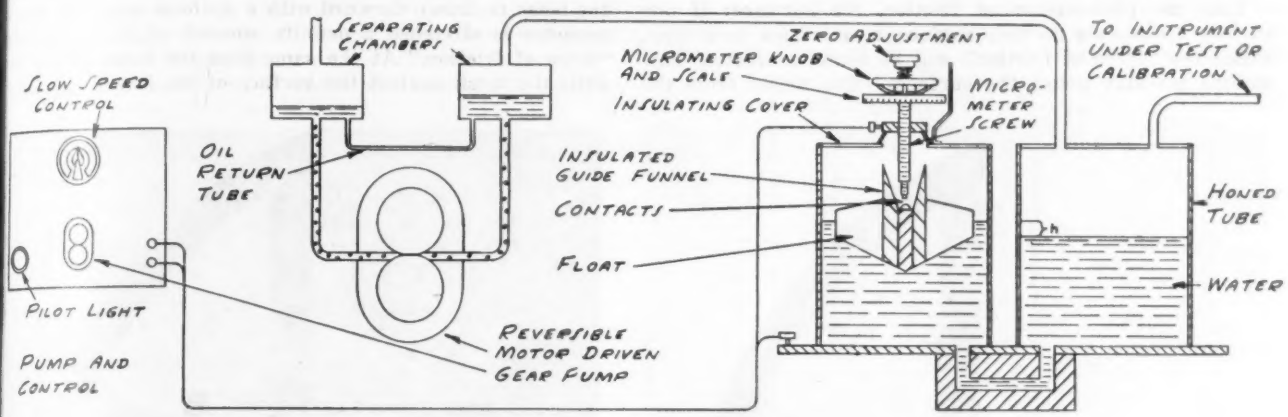

Fig. 4. Schematic diagram of Standard Manometer and Constant-pressure Control.

Frictional Phenomena in the Economy of Our Industrial Life

A Refresher for Instrument Men

By S. R. WILLIAMS, Professor of Physics, Amherst College, Amherst, Mass.

The April issue of *Instruments* carried a discussion of the structure of bodies throughout the universe. In this and several future issues there will appear the descriptions of a number of physical phenomena in which the way things are put together and are held together has an important bearing on these phenomena themselves.

Take the phenomenon of friction, for instance: if one surface slides over another surface, a resistance to sliding, called the "force of friction" will be found no matter how smooth we may polish the surfaces. This arises from the fact that, as we have discovered, matter is made up of small particles with a certain amount of free space between them and when a surface composed of these particles is polished there remain valleys between the hills composed of these small particles. When two such surfaces slide over each other, the hills on one project into the valleys of the other and thus the hills catch on one another.

Fig. 1. A wooden block *B* pulled along another wooden surface offers resistance to sliding called the force of friction. It is measured by the spring dynamometer *D*.

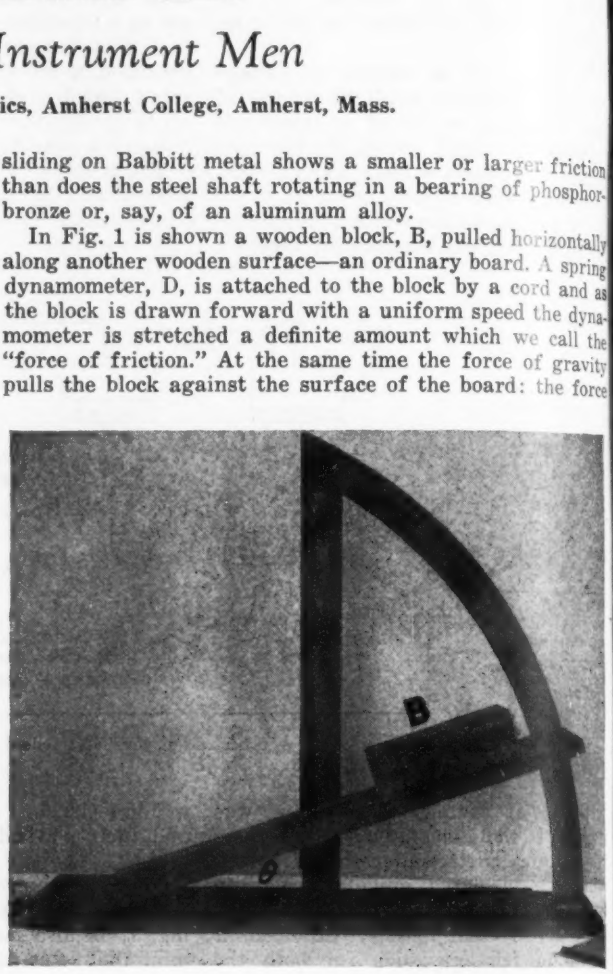

Fig. 2. The wooden block *B* slides down the inclined wooden board without acceleration. When this occurs, $\mu = \tan \theta$.

An excellent illustration of what is meant is to try to slide one surface of sandpaper over that of another. There is a decided resistance to sliding and, furthermore, the finer the sand the less will be the force of friction. We now begin to understand the phenomenon of friction because we understand how matter is put together.

Closely allied to this sliding of one surface over another is the cementing of two glass surfaces together after they have been highly polished and made as near plane surfaces as possible. When this has been done the atoms in the two surfaces may be brought so close together that the interatomic forces may act to produce resistance to sliding. Two glass surfaces may thus be brought together and after proper manipulation they unite as one piece of glass; no further motion can be produced.

To make the phenomenon still more understandable we must in some way begin to measure the forces of friction which exist between all bodies when they move over each other by a process of sliding. Thus, in our automobile engine bearings we have a steel shaft revolving in a bearing surface of Babbitt metal. Evidently here is a case where friction is not desirable; we should like to know if steel sliding on Babbitt metal shows a smaller or larger friction than does the steel shaft rotating in a bearing of phosphor-bronze or, say, of an aluminum alloy.

In Fig. 1 is shown a wooden block, B, pulled horizontally along another wooden surface—an ordinary board. A spring dynamometer, D, is attached to the block by a cord and as the block is drawn forward with a uniform speed the dynamometer is stretched a definite amount which we call the "force of friction." At the same time the force of gravity pulls the block against the surface of the board: the force normal to the surface of the board is the weight of the block—which can in turn be measured by the spring dynamometer.

It has been agreed by engineers that the ratio

$$\frac{\text{The Force of Friction}}{\text{The Force Normal to the Surface of Sliding}} = \frac{P}{W} = \mu$$

shall be called the coefficient of friction. It gives us a measure whereby we can determine whether one sliding surface is better than another for decreasing the effect of friction. Thus in Fig. 1 we have one surface of wood sliding over another surface of wood. If the force of friction $P = 100$ grams, and the force normal to the surface (the weight in this case, because the surface is horizontal) is $W = 300$ grams, then $\mu = 0.33+$.

Suppose now that instead of the wooden board we take a long strip of polished steel, say 6 feet long and 4 inches wide, then by dragging first a block of Babbitt metal and then a block of phosphor-bronze over the same steel surface we shall be in a position to determine which of the metal blocks will make the better bearing in which a steel shaft is to rotate. This coefficient of friction of dry metal on dry metal can be further reduced by lubrication with proper oils. Metal-on-metal friction can be increased by wetting.

The coefficient of friction as determined by the surfaces in Fig. 1 will be the coefficient of friction for wood on wood. As shown in the figure, the two surfaces move past each other with the fibers of wood in both surfaces parallel

to each other. The coefficient would be quite different if the fibers were cross-wise one to the other. Thus for oak on oak without lubricant the coefficient of friction is about 0.48 when the fibers are parallel in the two surfaces and about 0.34 when the fibers are at right angles. The reason for this is that the grain of the wood is made up of alternate layers of soft spring growth and hard summer growth. When these hard layers are at right angles to each other, they do not sink into each other's valleys as they do when parallel, and so the force of friction is less.

Thus far perhaps our emphasis has been on the baneful effects of friction. It also works to our advantage in many industrial processes. Without friction the belts by which our machinery is driven would be useless. The coefficient of friction of leather on steel when dry is about 0.56. If the leather is oily this will sink to around 0.15. Without friction we would not be able to use brakes on wagons, railway vehicles and automobiles. The coefficient of friction for auto brake bands runs around 0.4. Without friction we would not start to walk. Friction works in our favor in many cases, but often it is against us. We need in some cases to increase it and in others to reduce it.

An important problem in our industrial machinery is—How may we reduce the frictional forces in the bearings? Could we reduce friction to zero, the age of perpetual motion would have arrived, but we would still not be able to produce useful work; a machine without friction would just continue to run once it was set in motion.

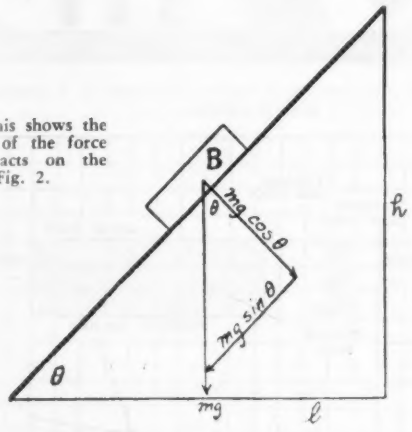

Fig. 3. This shows the components of the force mg as it acts on the block B in Fig. 2.

Another method for measuring the coefficient of friction is shown in Fig. 2. The same block and board as in Fig. 1 are used, only in this case the board is inclined to an angle where the block will just slide without any acceleration. Recalling the definition of μ that it is the ratio of the force parallel to the sliding surfaces and that normal to it, we can derive the following relations. In Fig. 3 the force of gravity acts vertically downwards on the block. This force is equal to mg and can be resolved into components parallel and normal to the sliding surfaces. The component parallel to the surfaces is $mg \sin \theta$ where θ is the angle of inclination which the plane makes with the horizontal. The component normal to the surface is $mg \cos \theta$. Substituting these in the equation:

$$\mu = \frac{P}{W} = \frac{mg \sin \theta}{mg \cos \theta} = \tan \theta,$$

we see that if the only force acting upon the block is gravity and that if it slides down the inclined way without acceleration, the coefficient of friction between the two surfaces may be found by the simple expedient of finding the angle θ where the block slides without acceleration. If h is the height of the upper end of the inclined plane and l is the length of the base, then $\mu = \tan \theta = h/l$.

If the angle θ is made just a trifle smaller and the block does not slide, then θ becomes the *angle of repose*. The angle of repose may also be illustrated by pouring sand out of a funnel and letting the sand run into piles. If the same size of sand is used in making any number of piles they will all have the same angle at the top of the conical pile formed. if different sizes of sand are used, the angles

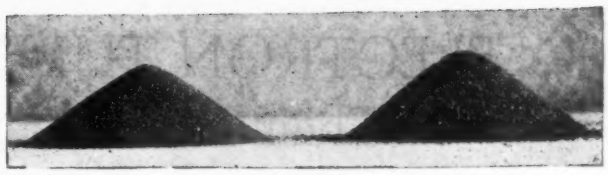

Fig. 4. Loose pilings of sand using two different sizes of grain.

at the top of the piles will vary. Fig. 4 shows two piles formed by sand screened so that the grains in the pile to the left will pass a No. 20 screen but not a No. 24 and in the pile to the right will pass No. 12 screen but not a No. 14. It would appear from the photograph and also by measurement with a protractor that the angle for the coarse sand is smaller than for the fine. The author recalls sitting in his office at Barnard College and looking across the Hudson River to where the Edison Electric Co. had piled up two huge piles of coal. The angles at the top of the two conical piles were the same as measured by a goniometer. Angles of repose are important in engineering. For example this angle of repose for loosely-piled earth has to be taken into consideration when designing railroad embankments.

The method illustrated by Fig. 2 may be modified by increasing θ to such an extent that the block will slide down the inclined plane with a decided acceleration. In the method shown in Fig. 2 the force parallel to the surface was $mg \sin \theta$ wherein θ was so adjusted that $mg \sin \theta$ was just equal but opposite to the frictional force. In the third method, illustrated in Fig. 5, the value of $mg \sin \theta$ is made large enough to give the block an acceleration down the plane, i.e., $mg \sin \theta$ is greater than the force of friction.

Let the force of friction be represented by F_f; then $F_f = \mu W = \mu mg \cos \theta$.

The resultant force down the inclined plane will then be

$$R = F - F_f = mg \ (\sin \theta - \mu \cos \theta)$$

and the acceleration $a = R/m$

or
$$a = \frac{mg \ (\sin \theta - \mu \cos \theta)}{m}$$
$$= g \ (\sin \theta - \mu \cos \theta)$$

whence
$$\mu = \frac{\sin \theta}{\cos \theta} - \frac{a}{g \cos \theta}$$
$$= \tan \theta - \frac{a}{g \cos \theta}$$

The advantage of this method over the angle of repose method is, that irregularities in the surface conditions of the plane are not so noticeable. If the angle θ is set so that

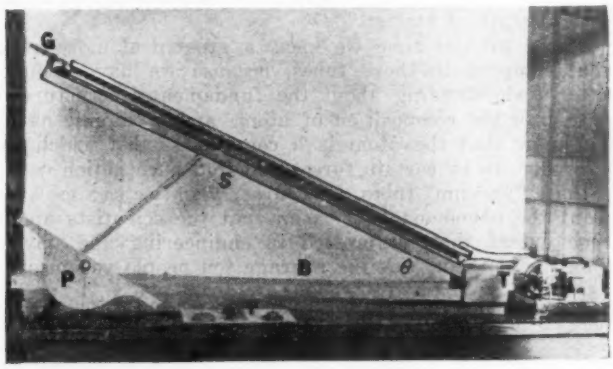

Fig. 5. Laboratory equipment for measuring the coefficient of friction. Here the block B slides with an acceleration a
$\mu = \tan \theta - a/(g \cos \theta)$

the block slides with no acceleration, it is set at a critical angle and slightest variation in μ either stops the block altogether or else it accelerates.

The apparatus as arranged for laboratory testing is shown in Fig. 5. A wooden strip S, 2″ × 6″ × 6 feet long, is hinged at its lower end to the base B. On this 2″ × 6″ strip is laid a strip of steel ½″ × 4″ × 6 feet long. The

(Continued on page 432)

ELECTRON TUBES—Their Principles and Their Instrumentation Applications

By ANDREW W. KRAMER, Managing Editor, *Power Plant Engineering*, Chicago, Ill.

XXI. COLD-CATHODE TUBES

So far in this study of electron tubes, little has been said about the simplest types of tubes—those known generally as the cold-cathode tubes. Brief reference was made to them in Article II as a matter of historical interest but they deserve further consideration, not only because they were the first electron tubes but because they have important applications in their modern forms.

As has already been explained, many years ago it was found that when two terminals were sealed into the ends of a glass tube and the tube exhausted of air, an electric current could be made to pass across the empty space inside by the application of sufficient voltage to the terminals. The voltage required was high but the fact that the smallest current could pass was astonishing and, at first, quite unexplainable. At that time there was no electron theory to account for the passage of electricity across empty space. The space was really not empty, there was rarefied air inside, but this did not particularly clarify the situation.

These were the first vacuum tubes, so-called, but not really vacuum tubes because even though they were exhausted there were countless millions of residual molecules of air still inside. If the potential applied to these tubes was high enough, a luminous discharge would fill the tube, often producing beautiful and weird effects. In view of present-day knowledge the nature of this luminous discharge is no mystery and we see a more practical application of the principle in the hundred million brilliant and colorful luminous tube signs throughout the civilized world—or rather before the civilized world was darkened by the blackout and the dimout.

Today we know that the luminosity is due to the effect of intense ionization of the gas molecules and atoms inside the tube—to the recombination of positive and negative ions and to excited atoms returning to normal states;* but at the time these discharges were first observed, the phenomenon was strange and mysterious. And why not? Here, for the first time, electricity was being observed apart from matter and there was no knowledge existing at that time to explain it. Sir William Crookes, after whom these first tubes were named, referred to the phenomenon as the "fourth state of matter."

At the present time we know a great deal more about what happens in these tubes, because we have a much better understanding about the fundamental structure of matter, of the composition of atoms and of atomic nuclei. We know that the atom is a complex system which can be broken up by certain forces and that such action occurs in these "vacuum" tubes. Of course, when we say *we* know about the phenomena, we mean that the scientists and to some extent those interested in engineering and physics know about them. Ask the average ten people you meet on the street how a neon sign or a fluorescent lamp works, why they give light, and all ten of them will not have the remotest idea of what you are talking about. But ask them as to the chances of the opposition party getting in power or who will win the World's Series, and they will declaim on these topics with conviction. Despite the current frenzy of the advertising men to glamorize "electronics" the average person today knows as little of electron tubes as he did before these devices existed—which is a rather sad commentary on our system and theories of education as well as on our native curiosity.

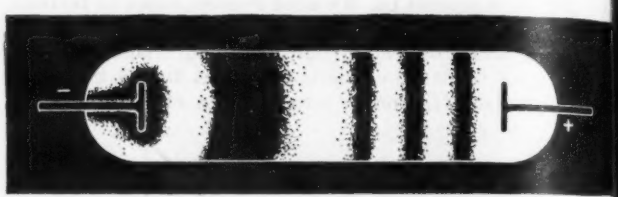

Fig. 136. Diagram of a typical discharge in a Crookes tube, showing a striated positive column.

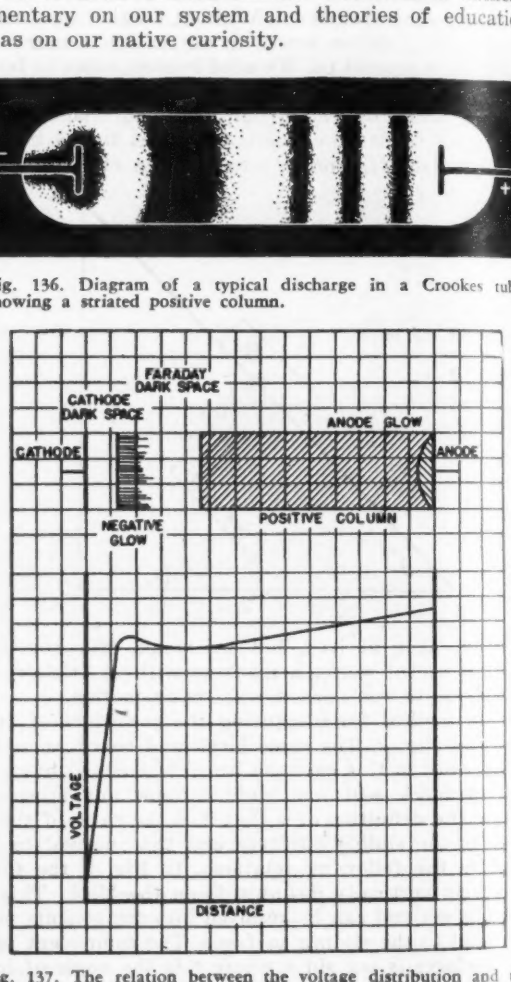

Fig. 137. The relation between the voltage distribution and the various luminous and dark portions of the discharge in a cold-cathode tube.

In view of our knowledge of thermionics, the action of the cold-cathode tube is interesting because in considering its operation the first question that arises is in regard to the origin of the primary electrons which bring about the ionization of the gas. In the thermionic tube, the electrons are emitted as a consequence of the thermal agitation of the molecular structure of the cathode—but in the cold-cathode tube there is no such thermal effect; both electrodes are identical; the current flows in either direction, depending upon the polarity of the terminals.

A clue to the action is provided by a study of the luminous discharge when a study potential is applied to the tube. Under such conditions the luminosity of the discharge throughout the length of the tube is not uniform. Close to the cathode there is a dark space, quite narrow but distinct and known as the Crookes or Hittorf dark space in honor of two of the early workers in the field of glow discharges. Next, in the direction of the anode, is a short

*By an excited atom is meant an atom which has had one or more of its external electrons displaced into orbits of higher energy level. Such a state can exist only for a very brief instant since under such conditions the atomic system is unstable and tends to return to normal. In returning to normal, the extra energy which was required to bring the atom to its excited state is given up as electromagnetic radiation, in this particular case as visible light.

In the electron tube, the energy necessary to bring an atom into an excited state is of course derived from the kinetic energy of the high-speed electrons traveling toward the anode. When such an electron collides with a normal atom, one of two things can happen: if the impact is sufficiently great, some of the external electrons may be removed and the atom ionized, or, if the impact is insufficient to cause ionization, it may merely cause the displacement of one or more of the external electrons from one orbit into others, resulting in what is known as an excited state. In reverting to normal from this excited state, the atom radiates energy in the form of light.

luminous section followed by another dark space, called the Faraday dark space, and finally another luminous portion known as the positive column, which extends across to the anode. The positive column occupies the major portion of the tube length. Often the surface of the anode is covered by a luminous layer called the anode glow.

The relative lengths of these various dark and light portions vary according to the degree of exhaustion of the tube. At certain gas pressures, the positive column is broken up by dark bands or striations.

A study of the voltage drop across the tube with respect to the various light and dark portions of the discharge as indicated in Fig. 137 provides an explanation of the mechanism of electron emission from cold cathodes. If the voltage distribution along the length of the tube is plotted underneath a diagram or section showing the light and dark portions of the discharge as in Fig. 137, it is apparent that nearly all of the voltage drop across the tube is concentrated across the first narrow Crookes or cathode dark space adjacent to the cathode.

Since the voltage gradient at this point is very high it might be thought that electrons could be pulled out of the surface of the cathode by the sheer force of the electrostatic attraction but a simple calcultaion of the forces involved show that this could not be possible. Another explanation must be resorted to if we are to explain the emission of electrons in a cold-cathode tube.

As a matter of fact the explanation is not simple—not nearly so simple as that of thermionic emission. To account for a discharge of electricity through such a tube it is necessary to assume that there is a certain amount of ionization in the gas before the application of voltage. Without the assumption of such initial ionization there is no way to account for the initiation of the discharge.

Fortunately, it is relatively simple to account for such initial ionization; indeed it would be much more difficult to prove absence of such ionization, especially since the development of our knowledge of cosmic rays. Owing to the ionizing influence of cosmic radiation from outer space or to emanations from radioactive material in the earth's crust, there always is a small amount of ionization in any gas, no matter how effectively we try to isolate the gas. The gamma rays of radium are capable of penetrating several inches of solid lead, and cosmic ray research has shown radiation of this character to be capable of passing through six feet of lead. Since such rays—x-rays, gamma rays and cosmic rays—are capable of ionizing atoms, it is evident that unless the most elaborate precautions were taken it would be extremely difficult to provide a tube of rarefied gas in which there were no ions. There will always be a few ions in any quantity of gas, however minute.

Assuming a certain number of positive and negative ions to be present in any gas, let us see what happens in a tube of rarefied air when voltage is applied to the terminals. Under the action of the electrostatic field, the positive ions will be driven toward the cathode while the negative ions, that is the electrons, will move toward the anode. The positive ions, being enormously more massive than the electrons, will accelerate less rapidly than the electrons but by virtue of their much greater mass their kinetic energy is correspondingly greater. The consequence of this high kinetic energy of the positive ions is that they bombard the cathode surface with such force as to knock electrons out of the surface of the metal. Upon leaving the surface of the metal these electrons find themselves in a region of high positive space charge due to the presence of large numbers of positive ions near the cathode and, by virtue of this charge, are accelerated in the direction of the anode. The high concentration of positive ions close to the cathode is responsible for the high potential gradient in the cathode dark space.

There will thus be a stream of electrons through the dark space, some of which have started from the cathode and acquired energy from the high potential gradient adjacent to the cathode; and others which have originated in the dark space itself which do not have so much energy. These electrons constitute a stream of energy passing out into the adjacent region, a stream of energy sufficient to ionize a large number of molecules without any help from the outside. The local field (created by the potential applied to the tube) does not need to supply energy to ionize the gas but merely to give a drift to ions made without its assistance. For this, an extremely weak field will suffice and, in the negative glow, which is the result of the ionization, the field is so feeble that often there is not a difference of potential of even one volt from one end to the other.

In effecting ionization in the negative glow, the electrons lose energy continually and, since the potential gradient in this region is so low, they slow up to such an extent that they are no longer able to ionize the gas. This results in the next dark space—the Faraday dark space.

There is, however, sufficient residual field in this region to again accelerate the electrons toward the anode, not so rapidly as in the cathode dark space but still enough so that after traveling a short distance they again attain sufficient energy to ionize the gas. Thus, the luminous positive column is accounted for.

As ionization begins again, a concentration of ions again occurs, resulting in the establishment of another space charge. This causes the potential gradient to rise, often to a point considerably above the ionization potential. What

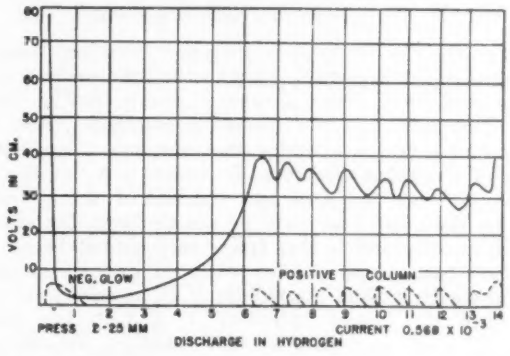

Fig. 138. The voltage distribution in a cold-cathode tube when the positive column is striated.

happens from here on depends upon the particular tube conditions, such as gas pressure, voltage, and design of the tube. If the energy of the electrons is high enough they will be able to ionize gas with little or no further assistance from the local field and there will be a region analogous to the negative glow where the electric force is extremely small. The energy of the eelctrons will be exhausted after passing through a certain distance toward the anode and again there will be a region corresponding to the Faraday dark space in which the electric field increases until another negative glow forms. Thus, the cycle begins again. Under these conditions the discharge will consist of a regular alternation of light and dark regions such as is exhibited in the striated positive column. A condition of this kind is depicted in Fig. 138.

Under certain conditions of gas pressure and potential, a different action is possible. If, instead of producing a large concentration of ions in certain regions giving rise to a variable voltage gradient, the degree of ionization is such as to result in just enough new ions to supply the loss of old ones due to recombination or attachment to molecules or diffusion to the sides of the tube, a steady discharge is possible and the result will be a uniform positive column. This is the type shown in Fig. 137.

The conditions under which one or the other type of discharge occurs are complex and they need not be considered in detail, since the phenomenon is referred to here only as a matter of passing interest, but they are subject to logical explanation in the manner briefly described.

The thing we are concerned with here is not so much the mechanism involved in producing the luminous and dark regions of the discharge, but the way electrons are emitted from the surface of the cold-cathode. This, is we have pointed out, is undoubtedly due to the bombardment of the cathode by the positive ions. That there is such a bom-

bardment can be shown by experiments with a perforated cathode. If a small hole is drilled in a disk-shaped cathode in a gaseous discharge tube, a stream of these positive ions can be detected passing through the opening at the back of the cathode. This stream can be bent by electric or magnetic fields and information obtained regarding their charge, their velocity and their mass.

So much for the Crookes tube. In its original form as described here, it has no practical application but it was the forerunner of all the different tubes existing today and the principles underlying its operation are those which govern the action of all cold-cathode tubes today.

As was pointed out, such a tube having simply two plain electrodes conducts current in either direction. By proper-

Fig. 139. The elements of a cold-cathode rectifier tube.

ly designing the electrodes, however, shaping them and spacing them, it is possible to give the tube unilateral conducting properties. Such a tube is shown in Fig. 139. As shown, this tube has two dissimilar electrodes, one, *A*, in the form of a hollow cylinder having a hole *C* opposite the middle of the other electrode, *B*, which is a flat disk. The distance between the disk and the end of the cylinder is less than the mean free path of the electron, therefore, an electron moving across this space only cannot bring about ionization because it collides with no gas molecules. An electron starting from the middle of *B*, however, may shoot right into the hollow cylinder, *A*, and in the distance available such an electron will produce ionization. In traveling from *B* to the outer edge of the hole *C*, it must, however, gain sufficient velocity to produce ionization since it gains no more velocity after it enters the hollow cylinder. All parts of the cylinder, naturally, are at the same potential, hence, there is no potential gradient to accelerate an electron inside the electrode *A*. This is the reason no electrons leave the inside of *A* to go to *B*.

With these characteristics, it is evident that when an alternating potential is applied to one tube it will conduct current when *A* is positive but not when it is negative and *B* is positive. This tube, therefore, is a rectifier.

The rectifying action, however, is not perfect because of the varying nature of the electronic collision. Suppose the mean free path of the electron to be one millimeter, that is to say, the average electron travels 1 mm. before colliding with an atom. There will, however, be some elec-

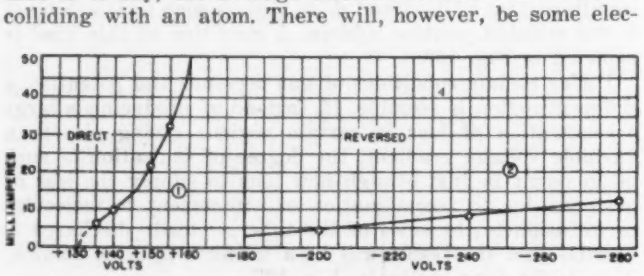

Fig. 140. The current-voltage characteristics of a cold-cathode rectifier.

trons which collide with atoms after traveling only 0.5 mm. or even much less, and, of course, these will produce some ionization; even in the inverse direction. Therefore, such tubes carry some current.

The voltage-current characteristics of a cold-cathode rectifier tube of this kind are shown in Fig. 140. It begins to conduct current at around 130 volts and as the voltage is increased the current rises rapidly. In the reverse direction, however, the current begins to flow at 180 volts and increases gradually but uniformly as the voltage is raised. As can be seen, the current in this direction is by no means as large as in the permeable direction, in fact below 180 volts it is negligible for all practical purposes.

For any purpose, however, the current-carrying capacity of such tubes is relatively low and their use for rectifying purposes has been superseded largely by tubes of the thermionic type. They are used for certain control purposes, however, and in this field their action is similar to the action of the hot-cathode triode or thyratron.

The principles involved in the use of cold-cathode tubes for control purposes are easily understood from Fig. 141. In this diagram the two sides of the circuit are identical and interchangeable. With all the resistance in on each side of the circuit, an extremely weak current flows in each side but no major discharge can take place because of the high resistance. If either of the resistances is made small enough so that a major discharge can take place, then the positive electrode in series with that resistance will be the anode and the other electrode will be the grid. Instead of having two identical variable resistors as shown in Fig.

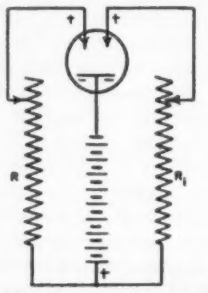

Fig. 141. Showing the principle of grid control in the cold-cathode tube.

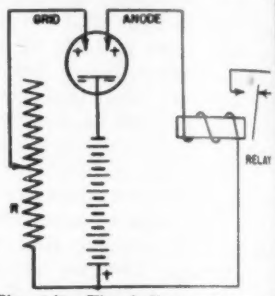

Fig. 142. The ballast resistance of Fig. 141 may be that of a relay coil, as shown here.

141, the ballast resistance may be of a coil of a relay as shown in Fig. 142. The resistance of such a relay may be of the order of 500 ohms but the grid resistance will be much higher.

For the purpose of explaining the action, let it be assumed that the tube is designed to discharge when the voltage across the cathode to anode is 200 volts. Suppose the anode voltage to be adjusted to a value of 199.8 volts without the grid connected. If the grid resistance is of such value that it will permit enough current to flow to increase the voltage by 0.2 volts the total voltage across the tube will be increased to 200 volts and the tube will discharge. In other words, the only function of the grid is to add that small increment of voltage which is needed to cause the tube to "break down" when the voltage is adjusted to a point just below breakdown value.

In the practical application of these tubes, the control resistor may be a device of the electronic type, a phototube for example. With such an arrangement, light falling upon the cathode of the phototube changes its normally high resistance to a lower value, causing the cold-cathode tube to discharge and actuate an electromagnetic relay. In this way, a relatively large amount of power can be held in check until released by the action of a light ray.

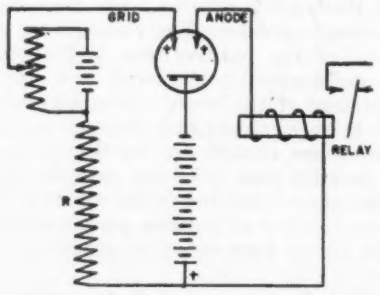

Fig. 143. Showing the use of a negative bias on the control grid.

Another way of operating these tubes is to provide the grid with a negative bias by means of a bias battery as shown in Fig. 143. In this case the discharge can occur only when the negative bias is decreased.

After the grid potential has been suitably altered to permit the tube to break down and conduct current, the grid is powerless to control the anode current further; it may be made highly negative but unless this negative potential is made extraordinarily large no effect is produced on the anode current. The grid can start the current but it cannot stop it. The only way to stop the anode current is to reduce the anode potential to such an extent that the arc discharge cannot be sustained and the discharge "goes out." If the anode voltage remains off for only a few microseconds, the state of ionization in the gas disappears and the grid again regains control. The anode current will not start again unless the grid bias voltage is again lowered sufficiently to allow the arc to restrike.

XXII. PRACTICAL FORMS OF COLD-CATHODE TUBES

From the foregoing description of the characteristics and operation of cold-cathode tubes, it will be evident that these tubes act very much like hot-cathode grid-controlled gas-filled tubes. The principal difference is in the current carrying capacity: the cold-cathode tubes are capable of carrying only comparatively small currents. In these tubes there is no proportionality between the anode current and the anode voltage: the tube either conducts to the limit of its ability or it conducts not at all. The tube is, therefore, a relay, with characteristics similar to those of an electromagnatic relay.

These cold-cathode "grid-glow" tubes belong to what is known generally as the "trigger" relay class. In some forms they are used to control relatively large amounts of power from extremely small actuating forces. The output of the grid-glow tube can of course be delivered to the grid circuit of thermionic amplifiers so that any amount of power can be controlled by an almost infinitesimally small actuating impulse. One of the first "stunt" applications of this principle was used a number of years ago when a steel mill executive sitting in his office in New York started the operation of a new rolling mill in Pennsylvania by waving his hand over a metal ball on his desk. The capacity effect of his hand on the ball was sufficient to alter the charge on the grid of a grid-glow tube, and thus, it initiated an impulse which passed through a series of amplifiers and relays and finally closed the starting contactors of the electric motors driving the steel mill.

An important and valuable application of the cold-cathode type of tube is to limit the voltage of a circuit below a certain maximum value — to keep dangerous high voltage surges from causing injury to electrical apparatus connected to the line. Such a tube, like any other of the cold-cathode gaseous tubes, takes a reasonably high voltage to break down, and when once broken down it carries high currents at reasonably low voltages.

The Type 874 neon-filled or (in an earlier model) argon-filled tube, used in many of the earlier radio sets to limit the voltage on the amplifier tubes, is a tube of this kind. In this tube a cylindrical electrode serves as the cathode and an axially placed stiff wire is the anode. The breakdown voltage of this tube is 125 volts when the wire electrode is positive and the voltage then drops to its safe operating value of 90 volts. With these characteristics the tube functions well as a simple voltage regulator.

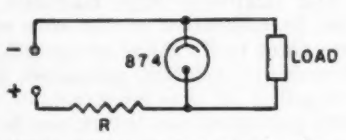

Fig. 144. A simple voltage regulator circuit using a glow tube.

A simple circuit is shown in Fig. 144. Resistance R is high enough to limit the tube current to the "normal" range when the load current is zero. Load current increases the voltage drop across the resistance and since the source of supply is constant the voltage across the tube is reduced. A small reduction of the voltage in the "normal" current range, however, results in a comparatively large decrease in tube current, which increases the IR drop. Small variations of the load current therefore cause compensating variations of tube current, the voltage across the tube remaining essentially constant. Thus, the tube acts as a voltage regulator. A tube designed for this purpose should have a large cathode area in order to give a large range of "normal" current. It is for this reason that the 874 has a cylindrical cathode which is large compared to the wire anode.

Larger tubes of this kind but having symmetrical electrodes are used for operation on a-c. lines. The continuous current rating of such a tube may be only a quarter of an ampere but for a period of the order of one second it may carry as much as 200 amperes. Thus, with such a tube connected in a circuit, a high energy surge appearing on the line will discharge through the tube without damaging apparatus connected to the line. In this capacity glow tubes have been used to dissipate the energy released by the opening of a circuit containing a large inductance such as the field coil of a generator.

Since the voltage across a tube of the 874 type tends to remain constant, it offers a method of providing a number of constant voltages from a single source. By connecting a number of these tubes in series or by the use of a tube called the "Stabilvolt" which has a number of additional electrodes between the anode and the cathode as shown in

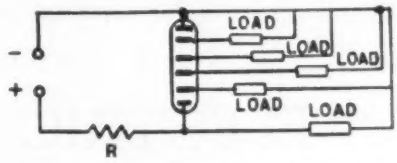

Fig. 145. A glow tube with several electrodes used as a voltage divider.

Fig. 145, a number of constant voltages can be obtained from a single source.

Cold-cathode tubes can also be used as light sources. Perhaps the most notable example of the use of gaseous tubes for this purpose is in the "neon" sign lamp which forms so conspicuous a part of our city life.* The neon lamp is somewhat outside of the scope of this discussion but it is a true electron tube. The light is due to the ionization and recombination of the ionized atoms of gas in the tube brought about by the high potential across the tube. The color of the light is entirely a function of the composition of the gas; it is related to the energies with which the electrons of various gas atoms are held in their orbits. Although we generally refer to the gaseous tube sign lamp as a "neon" light, actually various other gases are also used in such lamps. Helium and argon are used to a considerable extent. If the tube is filled with neon, the glow is orange-red. If helium is used, the glow is yellow. A blue glow is produced by mixing mercury with argon and neon. Various other distinctive colors are obtained by using colored glass tubing. Thus, a mercury-argon mixture in a yellow glass tube gives a green light.

The mechanism of this discharge in these lamps is that discussed in the preceding article. The tubes contain an inert gas at a few millimeters pressure between cold cathodes. In these tubes the cathode glow is an insignificant part of the light-emitting region of the discharge and most of the luminosity comes from the long positive column. While such tubes require only a moderate voltage to maintain the glow, a high voltage is needed to initiate the discharge. Because of this, neon tube signs are supplied from special "luminous tube" type transformers, provided with magnetic shunts so as to give poor regulation. Such transformers provide high voltage on open circuit or at light load but deliver a low voltage after the discharge occurs. Normally these tubes require from 100 to 200 volts per foot of length, depending upon the dimensions of the glass tubing used. A typical transformer delivers 10,000 volts on open circuit and 30 milliamperes on short circuit.

The neon lamp used in display signs discussed in the

(Continued on page 424)

*S. C. Miller and D. G. Fink. "Neon Signs." McGraw-Hill Book Co., Inc., 1935.

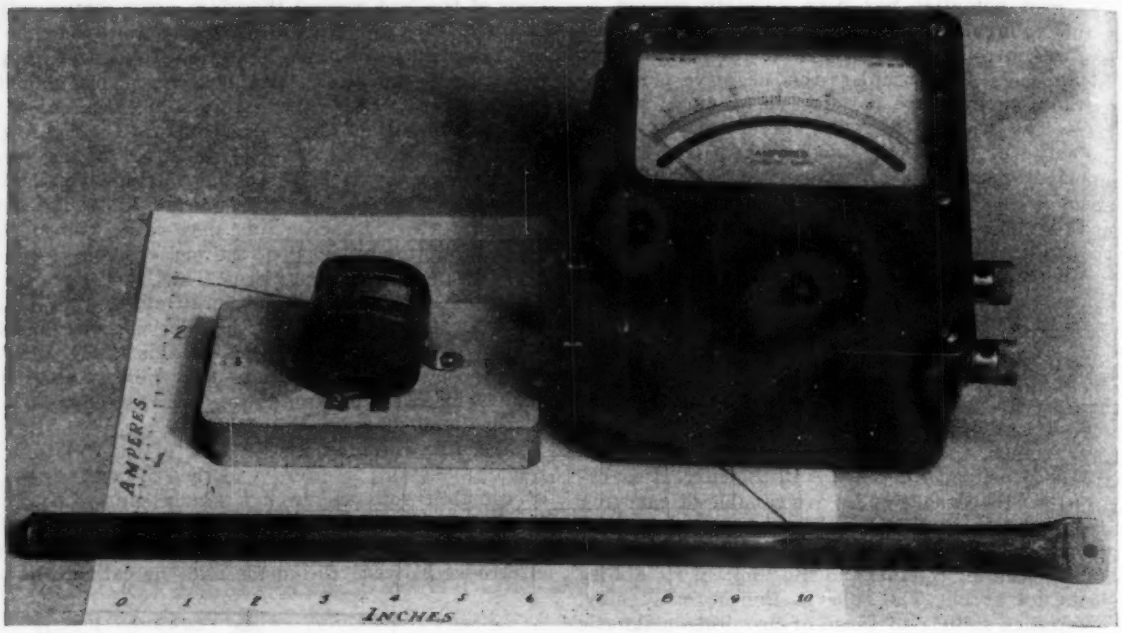

Fig. 45. Components of a series-type gaging system.

ELECTRIC GAGING METHODS for Strain, Movement, Pressure and Vibration

By HOWARD C. ROBERTS, University of Illinois

IV. GAGING METHODS BASED ON VARIATIONS OF INDUCTANCE

(Continued)

§5. Electric Circuits

The electric circuits used in combination with variable-inductance gaging elements comprise these three general classes:

Simple series circuits;
Series-opposition circuits; and
Bridge-type circuits.

Any of the three may include electronic amplification.

An understanding of the operation of gages employing magnetic principles requires consideration of the magnetic as well as of the electric circuits. In certain installations in which movement is measured it is desirable to make the moving part itself part of the magnetic circuit. Magnetic methods for detecting discontinuities or flaws, or measuring plate thickness, necessarily employ magnetic circuits which include the portion of the material being examined. Consideration of these factors therefore will be included in the discussion of circuits.

One of the outstanding features of the inductance-type gage is its ability to provide sufficient current to actuate an indicating or recording instrument without added amplification, even under dynamic conditions. This facility makes for less costly and less complicated equipment, fewer operating difficulties and lower maintenance costs. In this article, only the basic types of electric and magnetic circuits will be described; where amplification is required for some purpose this will be stated, but detailed descriptions of amplifiers will be included in a later article.

Three components only are required for the simplest series-type gaging circuit: (1) a source of power, (2) a variable-impedance gaging element, and (3) an instrument with which to measure the current flowing through the gaging element. The components of such a system are shown in Fig. 45. They are part of an installation for remote indication of water level at several points along a channel. The laminated tapered armature is attached through a cord-and-pulley arrangement to a float, so that changes in the water level change the position of the armature within the coil. (Compare to Fig. 34 C.) The current through the circuit is indicated by the a-c. ammeter; a switching device is available so that the indicating instrument may be connected at will to any one of several pick-ups. The exciting current is 60-cycle from the line. Similar systems have been used for measuring such small displacements as those of the tiny hydrometer float (iron-weighted) used in measuring the specific gravity of small samples of liquid,[73] or the strains in a torsion-type dynamometer used for measuring horse-power.[74] These devices are best calibrated by experiment.

These series circuits have several limitations, of which the most serious are these: (1) change in exciting voltage causes change in output; and (2) the current through the indicating instrument is the total current flowing, so that the magnitude being measured is indicated in terms of a *change* in deflection. Since the change in current may be only 20% to 30% of the total current, only a part of the scale of the indicating instrument is actually used, and possible error in observation is increased thereby. In some installations, the currents flowing may be as great as several amperes, so that it is not permissible to neglect the effect of ohmic resistance. The magnetic fields then are quite strong, and relatively large magnetic forces exist. There may also be saturation of the core of the gaging element at some point in its range of operation, and under such circumstances the relation previously given for describing the variation of impedance cannot be used—one no longer knows just what the inductance is at any time. It therefore is necessary in such systems to maintain both frequency and wave-form of the exciting current constant.

Because of its simplicity, low cost, and freedom from operating difficulties, the series-type circuit is widely used

(73) A. R. Richards. An Electromagnetic Densitometer. *Industrial and Engineering Chemistry, Analytical Edition*, Vol. 14, 1942, pages 595-596.

(74) Anon. The Moullin Torsion Meter. *Engineering* (London), Vol. 117, 1924, pages 764-765.

in industrial applications. Installations like that described above have been used to indicate water levels in city reservoirs,[75] as well as liquid levels in tanks and channels. In many of these installations, indicating instruments having non-linear scales have been used; the portion of the scale employed (in terms of length) is thus made large, and the accuracy is thereby increased. The ammeter in Fig. 45 has a scale which is expanded in its upper part.

The "simplest" series circuit, just described, is only one of those which has attained wide industrial use. Instruments employing mutual-inductance elements in series-type circuits are also widely used. Recording and control devices employing essentially the circuit drawn in Fig. 46, with

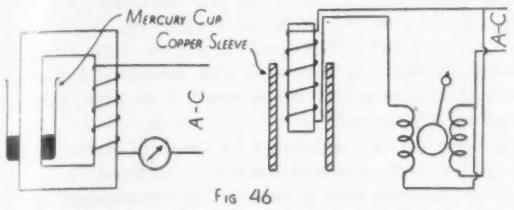

Fig. 46

the forms of gaging elements shown there, have had wide application for indicating and recording liquid level or flow,[76,77] or movement.[78] Especially in this country, the mercury-cup primary element has been employed in many commercial instruments; most of them are inferential devices for measuring liquid pressures and flow. In both types of primary elements shown in Fig. 46, the impedance of the element is changed by changing the mutual inductance between the core and the copper or mercury "secondary winding" of the element. The use of a ratio-type meter (a crossed-coil ratiometer or a differential galvanometer) is illustrated in this drawing likewise; such an instrument can compensate for changes in exciting voltage. Or a watt-hour meter can be used, to provide an integrated output.[76]

Other series circuits, depending not upon the admittance of a single winding but upon the coupling between two windings, are used in measurement of plate thickness,[79,80] thickness of insulating coatings on magnetic or conducting sheets,[80,81] and as electrical micrometers to measure the change in position of the iron armature of a variable air-gap element.[79,80] Instruments are also available for measuring displacements through the movement of an iron armature coupling the two coils of a transformer, as in Fig. 47; these are used for telemetering float positions and

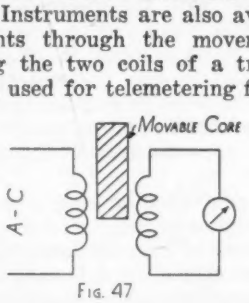

Fig. 47

the like.[77] The change in coupling may be produced by the change in magnetic properties of an armature, instead of its position; one instrument (the Carbanalyzer) can measure the carbon content of a heat of steel in the time required for the visual examination previously employed.[82]

(75) H. N. Jenks. Electrically Operated Gages for Filters. *Engineering News-Record*, Vol. 95, 1925, pages 346-348.

(76) H. Olken. Electrical Telemetering. *Instruments*, Vol. 5, 1932, pages 66-74.

(77) R. J. S. Pigott. A Decade of Progress in Industrial Fluid Metering and Automatic Control. *Instruments*, Vol. 11, 1938, pages 19-25.

(78) G. F. Tagg. Remote Indication and Control Devices. *Journal of Scientific Instruments* (London), Vol. 10, 1938, pages 65-71.

(79) A. Albrecht. Elektrische Laengenmesser. *Helios*, Vol. 38, 1932, pages 209-210.

(80) J. D. Campbell. Special Electrical Applications in the Steel Industry. *Iron and Steel Engineer*, Vol. 19, Feb. 1942, pages 78-89.

(81) W. H. Tait. An Instrument for Measuring the Thickness of Coatings on Metal. *Journal of Scientific Instruments* (London), Vol. 14, 1937, pages 341-343.

(82) Anon. A New Instrument for the Magnetic Determination of Carbon in a Steel Bath. *The Laboratory* (Fisher Scientific Company), Vol. 11, 1939, pages 34-36.

(Recently announced devices for much the same sort of measurement employ permeability of the metal[83] and its core-loss characteristics[84] as criteria.) Devices are in use for measuring movement (as the movement or expansion of a steam turbine during its warm-up period[85]) which employ two separate coils each with its own core, so installed as to cause the movement being measured to change the position of the cores transversely. Even the mutual-inductance unit of Fig. 41 E operates in a series circuit; in it (as in some others) some portions of the circuit are magnetic and some electric, but all are in series.

Devices are available in which the two windings are not separate but are auto-transformer windings. Commercial units of this type are used for indicating and recording beater roll position in paper mills[86] and for many other uses as well.[87]

The electric circuits used in these devices are alike in principle. Fig. 47 is typical. Excitation is usually provided by power-line current at 60 cycles, and may if necessary be regulated by a constant-voltage device. The circuit is basically a simple series connection; the indicating instrument may be an a-c. instrument, or a d-c. instrument with rectifier. The exciting voltages are often quite low (less than one volt) and the output is of the order of millivolts. For greater convenience and accuracy, the instruments often have either suppressed-zero scales or scales which are expanded over their upper ranges. Protection for the indicating instrument is afforded by the circuit of Fig. 47; in this circuit the absence of a specimen causes the output voltage to become low (it is smallest when the two windings are on opposite legs of a U-shaped core). In circuits of the type of Fig. 46, if the specimen or the armature is inadvertently removed, the current may rise to a value high enough to endanger the indicating instrument.

§6. Series-opposition Circuits.

Series-opposition (bucking-type) circuits are those in which the current carried by the variable-impedance gaging element is balanced by an opposing current in such a manner as to make their difference proportional to the change in the gage current. This eliminates the large steady component from the indicating instrument, and if properly applied can also afford compensation for other sources of error.

Series-opposition circuits may be set up with variable-impedance gaging elements like those used in the series circuits just described, by providing from some other source a bucking current having the necessary characteristics. Or an inductance-ratio element may be employed in a series-opposition circuit, in which the output of one portion of the pick-up is balanced against the other. Mutual-inductance gaging elements are often used in the same manner.

The combination, or comparison, of the two currents involved may be made by any of several practical methods. Since alternating current is used to excite the gage elements, it is possible to employ some types of mutual-inductance gaging elements in such a manner as to perform this combination within the element itself. Or, alternatively, the combination may be accomplished by an external circuit, or in an indicating or recording instrument of suitable design.

In Fig. 37B was shown the schematic circuit of a mutual-inductance pick-up embodying the series-opposition principle; it was described as being suitable for the measurement of small movements. The two outer coils are connected together mechanically, and so connected electrically that their magnetic fields oppose in the space between

(83) [General Electric Company.] Magnetic Comparator. *Instruments*, Vol. 17, 1944, page 240.

(84) W. A. Knoop, Jr. Rapid Non-destructive Material Testing with the Cathode-ray Oscillograph. *Instruments*, Vol. 16, 1943, pages 14-15.

(85) H. Steen-Johnsen. Supervising Instruments for the 165,000-kw. Turbine at the Richmond Station. *Transactions American Society of Mechanical Engineers*, Vol. 58, 1936, pages 621-626.

(86) [Thwing Instrument Company.] Thickness Recorder. *Instruments*, Vol. 7, 1934, page 97.

(87) [Esterline-Angus Company.] Position Recorder. *Instruments*, Vol. 3, 1930, pages 265-266.

them. Thus, in this intervening space there is a small region devoid of effective magnetic field; a coil placed in this region has no current induced within it. But if it is moved ever so little in either direction the nullification is no longer in effect over the entire coil and current will be induced. It will vary in magnitude with the amount of displacement and in phase with the direction.

The same electric circuit is used in the construction of a pick-up in which all three coils are fixed in position, and so adjusted that no current is induced in the secondary coil. If then some material having either magnetic or conducting properties is brought near this assembly, the field is distorted and current will be induced. The device is therefore capable of detecting the presence or measuring the amounts (within limits) of the conducting or magnetic material placed near the coil assembly. Fig. 48A is a diagram of such a pick-up. For measurement of plate thickness it is ordinarily best to make the central coil the primary and the two outer coils the secondary. For inspection of a small-diameter rod or tube passing through the coil axially, it may be best to make the outer coils the primary and the central coil the secondary. Proper placement and shape of the coils is necessary for most efficient operation; the magnetic fields produced by the exciting coil—the primary—must pass through the specimen as fully as possible, and must likewise thread the secondary coils.

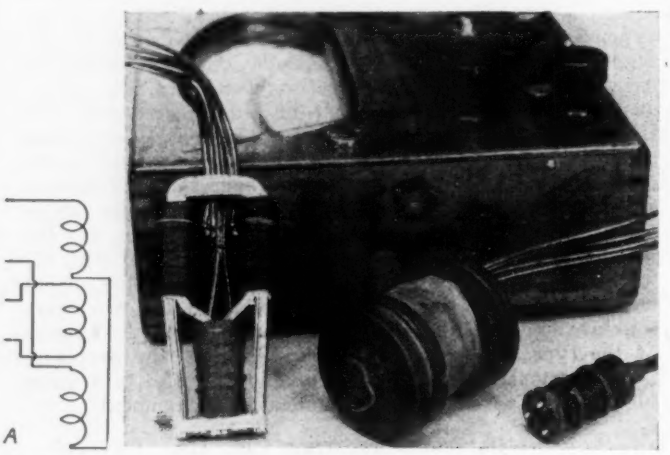

Fig. 48 B. Series-opposition type gages.

Three pick-up heads designed for measuring plate thickness or for detecting discontinuities in materials are shown in Fig. 48B. Left to right, they are, first, a variable air-gap transformer unit after the general form of Fig. 38D; second, an iron-core series-opposition unit of the form diagrammed in Fig. 48A; and third, a similar air-core unit. Their dimensions may be estimated by comparing them to the microammeter in the background. The impedance of these units under operating conditions is approximately 100 ohms each. In use, they are cased in protective coverings, either of plastic, or of copper if it is necessary to protect them against stray fields.

It is essential with devices of this kind that in operation a uniform distance be maintained between gage head and work; a change in this distance will obviously cause a change in the output of the gage circuit. (Exception: the unit at the left in Fig. 48B can be so connected that it is sensitive only to differences existing between its two sides.) Means for maintaining this spacing must be provided; in the gages illustrated a three-point support is used, and the distance separating the coils and the work is made relatively large, so that a small change in the distance will cause less change in output. The sensitivity is lowered, but ordinarily there is an excess of sensitivity.

The first two of the gage heads illustrated in Fig. 48B are designed to be used on magnetic materials, but may be used on non-magnetic materials with lowered sensitivity. The first has all connections to the coils made accessible. It therefore is possible to connect the two exciting coils in series-opposition, when the third coil will detect discontinuities between the two sides of the pick-up face; or the exciting coils can be connected in parallel, when the instrument will be sensitive to the effect of material placed entirely across the face. The second pick-up is connected in the manner indicated by Fig. 48A but, again, the connections are brought out, so that either one or both of the secondary coils can be employed. It is more sensitive as an eddy-current device if the more remote secondary coil is not employed. Both pick-ups are excited by a 60-cycle supply at low voltage.

The third gage head illustrated was designed and used for the detection of flaws in welded seams of aluminum vessels. It is excited by high frequency, 5,000 cycles per second being most efficient. The use of high frequencies is desirable because it increases the speed of the work, and because it makes possible the control of penetration of the measuring influence.[88]

This type of coil assembly is used in devices operating on large as well as small scales; it is used in the Hughes Induction Balance and a number of commercial devices for ore-finding, metal-locating, and for the detection of metallic objects in packages or upon persons; as in the search-rooms established for visitors to prisons.[89] A modified form is used for the inspection of cigars to detect small particles of metal accidentally included within them during manufacture.[90] Such devices can detect any material having a magnetic permeability differing from that of air. They have been used to inspect steel cables and rods,[91,92] condenser tubing and similar products,[92] and the tungsten wires used in radio tube construction.[93] As indicators they have employed oscillators which give forth an audible tone upon the incidence of a discontinuity,[92] instruments which indicated the condition continually,[93] and relay devices which gave any other desired indication.[94]

Plate-thickness gages are ordinarily designed to operate with high flux densities on magnetic materials, therefore in operation the measuring head will exert a strong pull against the plate. This is an advantage, since the gaging head will hold itself in place while the operator has both hands free for other purposes; it also assures close and reproducible contact with the specimen. Eddy-current type gages are frequently employed to inspect large sheets of material, and in these systems it often is convenient to cause the gage head to scan the material mechanically.[95] Large separation between gage head and material is used, but electronic amplification is ordinarily available, so that ample sensitivity is available. The magnetic forces are small.

Other mutual-inductance gaging elements which have been used in series-opposition circuits are the variable-air-gap transformers of Fig. 38C and Fig. 41A. These constructions are used in the Ford Induction Micrometer[96,97] and in the dynamometers and torsion-measuring instruments of the same manufacture. The gage element of Fig. 41A with the electrical connections sketched there is used in the basic form of these instruments; an alternating-current galvanometer is used as an indicating instrument.

(88) Ross Gunn. An Eddy-current Method of Flaw Detection in Non-magnetic Materials. *Journal of Applied Mechanics*, Vol. 8, 1941, pages A-22 to A-26.

(89) C. A. Heiland. Geophysical Exploration. Prentice-Hall, Inc., 1940. 1,000 pages.

(90) W. C. Broekhuysen. A Practical Metal Detector. *Electronics*, Vol. 11, April 1938, pages 17-19.

(91) H. Herbst. Elektromagnetische Verfahren zur Ermittlung von ausserlich nicht erkennenbaren Drahtbruechen. *Zeitschrift des Verein Deutsche Ingenieure*, Vol. 76, 1932, pages 557-558.

(92) [General Electric Company.] Wire and Tube Flaw Locator. *Instruments*, Vol. 6, 1933, page 88.

(93) D. T. O'Dell. Apparatus for the Detection of Splits in Tungsten Wire. *Journal of Scientific Instruments* (London), Vol. 20, 1943, page 147.

(94) [General Electric Company.] Tube Flaw Detector. *Instruments*, Vol. 16, 1943, page 708.

(95) Irwin Vigness, J. E. Dinger, and Ross Gunn. Eddy Current Type Flaw Detectors for Non-magnetic Materials. *Journal of Applied Physics*, Vol. 13, 1942, pages 377-383.

(96) J. M. Ford. British Patent No. 166,317.

(97) J. M. Ford. British Patent No. 215,986.

In later forms a type of bridge construction has been employed.

Inductance-ratio gaging elements have been used, with the connection from the three terminals so made as to provide a bucking action. The indicating device used with these pick-ups is often the ratio meter. Such a circuit is shown in Fig. 49A. In this circuit (originally used in torsion meters[98]) the use of the ratio meter is desirable because it obviates the need of maintaining exciting current at constant voltage. The ratio meter indicates the ratio of the currents flowing through its two coils, regardless of the voltage applied to the circuit (provided it is greater than the critical value for operation). Since both inductance and resistance are present, however, the frequency and the wave-form of the exciting current must be kept constant.

A transformer has also been used to combine the two currents which are obtained from an inductance-ratio element or from two series elements; a suitable transformer for the purpose has three windings, two of which are alike and closely coupled. A "hybrid coil" of the telephone type is such a transformer. The indicating instrument in the circuit is often a low-range a-c. voltmeter. It indicates magnitude of displacement but not direction.

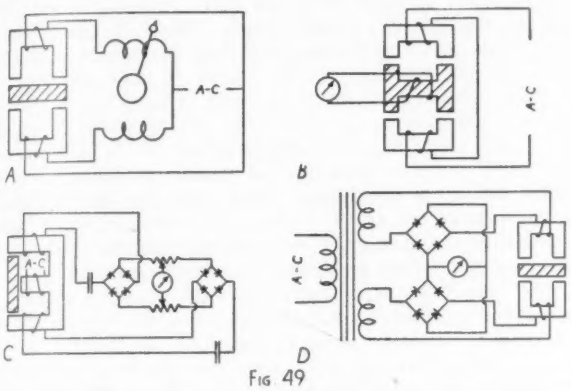

FIG 49

Strictly speaking, any device which can be so connected as to indicate the ratio or the difference of two currents can be applied as the indicating device in series-opposition circuits. Wattmeters are used as integrating devices.[76] Differential telephones, dynamometer-type voltmeters, and even amplifiers with suitable input circuits have been used.

Three-winding mutual-inductance gaging elements are well suited to series-opposition circuits; in such a gaging element the combination of currents is performed by reason of the internal inductive coupling of the pick-up itself. (The elements sketched in Fig. 39 provide this action.) Fig. 49B is a diagram showing an entire circuit. Similar circuits, in which the combination of currents is made after they have been rectified, with the difference current indicated on a d-c. instrument, have been used recently for precision measurement of screw-threads[99] and for continuous recording of stock thickness in a strip-rolling mill.[100] These circuits appear as Fig. 49C and Fig. 49D. As may be seen, they closely resemble true bridge circuits, but differ in that the indicating instruments are connected through rectifying elements in such manner as to indicate the difference between the currents in the two sides of a symmetrical circuit.

Of the many other bucking-type circuits which have been employed in gaging devices, there are three which because of their simplicity in construction and use, and relatively high efficiency, deserve mention here. They are drawn in Fig. 50. The first of the three is an adaptation of the circuit of Fig. 49A; it is here modified to employ rectifiers in conjunction with the ratio meter.[101] The second (50B)

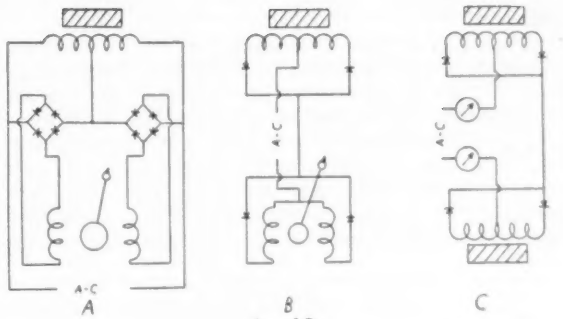

FIG 50

is another modification of the same circuit.[101] The third (50C) is a further modification, so arranged as to permit the system to be used either as a deflection-type indicator or as a null-point device; if the balancing element is adjusted until the deflection of the indicating instrument is zero, the two elements are similarly adjusted. Two or more indicating instruments can be used, thus enabling the system to be used for position comparison and control.[102] The indicating instrument is a low-range d-c. ammeter.

§7. Bridge-type Circuits

A bridge circuit is a network (of six or more conductors) which is so arranged that by suitable adjustment of its branches its output can be reduced to zero, and which when so adjusted can have its source of excitation and its detecting device interchanged without affecting the condition of balance. It is basically different from a series-opposition circuit, although the two often resemble each other physically.

Bridge networks used with a-c. excitation are classified by Hague[103] under these five headings:

(1) Containing resistance and self-inductance;

(2) Containing resistance and capacitance;

(3) Containing resistance, self-inductance, and capacitance;

(4) Containing resistance, self-inductance, and mutual inductance; and

(5) Containing resistance, self-inductance, mutual inductance, and capacitance.

Of these, the first and fourth are most used in variable-inductance gaging systems. In most such systems the arrangement is made such that capacitance can be ignored.

A large proportion of the variable-inductance gaging circuits now in use are low-impedance circuits designed to provide sufficient current output to actuate the indicating or recording devices without amplification. In such systems the ohmic resistance of the components is quite low; it is a common practice to make the impedances of the gaging and balancing elements about 100 ohms; of this impedance, the greater portion comes from the inductance of the element. When high-impedance elements are used, it is customary to employ either indicating instruments requiring low currents, or to provide electronic amplification. Amplification is also required if the frequency of the phenomena being measured is high, since recording instruments suitable for high-frequency recording require fairly heavy currents.

In general it may be said that if the capacitive reactances are high compared to the other impedances present they can be safely ignored. Resistance and inductance balances only will then be required.

The equal-arm inductance bridge is little used in electric gaging practice, except in the special case of the inductance balance. The circuits most used are of the ratio-bridge type, in which a unity-ratio pair of fixed arms is used, and the other pair of arms is composed of two other impedance elements; these may be either a single inductance-ratio gaging element, or a gaging element and a similar balancing element if they are of the variable-inductance type. Thus a single bridge circuit can be used for different pur-

(98) Georg Keinath. Ein neuer elektrischer Verdrehungsmesser. *Dingler's Polytechnische Journal*, Vol. 335, 1920, pages 265-268.

(99) H. T. Rights. New Electromagnetic Method of Measuring Screwthread Leads to a Few Millionths of an Inch. *Instruments*, Vol. 17, 1944, pages 134-135.

(100) C. C. Mason. The Trends of Instrument Design. *Journal of Scientific Instruments* (London), Vol. 17, 1938, pages 323-333.

(101) A. Linford. The Electrical Transmission of Flow and Level Record. *Beama Journal*, Vol. 47, 1940, pages 97-101.

(102) L. H. Bainbridge-Bell. Electrical Instruments. *Journal of Scientific Instruments* (London), Vol. 14, 1937, pages 57-61.

(103) Bernard Hague. Alternating Current Bridge Methods. Pitman (London), 1938, 600 pages. Chapter 4.

poses with gaging elements having somewhat different impedances.[104]

In Fig. 51A is shown a circuit which is perhaps the most widely used of all those for variable-inductance gaging systems.[104] In it two arms are provided by the center-tapped inductor and indicated by Z_3 and Z_4, while the other two arms are provided by the gage and the balancing element, or by the two parts of an inductance-ratio pick-up; they are denoted by Z_1 and Z_2. (The symbol Z indicates impedance.) If it is more convenient for a particular application, the source and the detector may be interchanged.

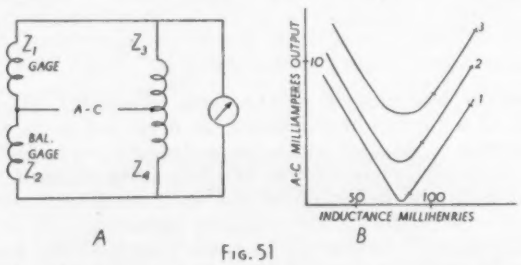

FIG. 51

The center-tapped inductor is actually a pair of unity-ratio inductive arms for the bridge circuit, and for best results should be carefully prepared with the closest possible coupling and the highest mutual inductance.

In this circuit, the ohmic resistances provide only a small part of the total impedances. The exciting frequency for dynamic measurements is high (2,000 and 4,000 cycles per second are widely used), the impedances of the gage elements are of the order of 100 ohms, while the ohmic resistance of these elements is seldom as high as 10 ohms. If an inductance-ratio pick-up is employed, or if the balancing element is installed near the point of measurement, the lead resistances of both gage arms of the bridge can be made equal, and a resistance balance will be assured. In Fig. 51B are shown curves indicating the variation of output current from a bridge of the type of Fig. 51A with variation in the impedance of one arm of the bridge. In all three curves, the bridge is at one point (at minimum current output) balanced so far as inductance is concerned. In curve 1, a resistance balance was attained at the same point, and the output current approaches zero. In curve 2, a resistance of 2 ohms was added in series with the gaging element and left there while the inductance was varied. The output current falls to a minimum which represents a value higher than that in curve 1. In curve 3 the added resistance was 5 ohms. The effect of the lack of resistance balance is shown clearly; it is greatest near the point of balance. If the unbalance is large the effect of the resistance on the slope of the output curve can be ignored.

It is desirable, from the standpoint of accuracy, to employ an inductance-ratio pick-up, or to install the balancing element near the point of application of the measuring element, and to use connecting leads of the same length and the same material for all connections to these elements. Any change due to temperature or other atmospheric change

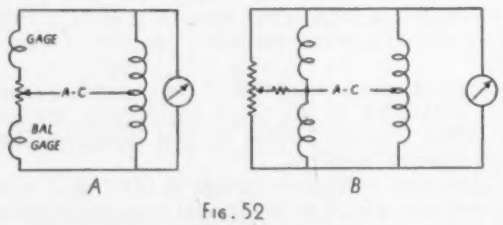

FIG. 52

will then be common to both gage arms of the bridge, and will balance out. In practice, however, it often is satisfactory and more convenient to employ variable-inductance gaging elements and to install the balancing elements near the recording apparatus. Devices for adjusting the resistance balance can be built into the bridge circuit; two are drawn in Fig. 52. In the first, the adjustment is made by adding small increments of resistance in series with the bridge arms which require greater ohmic resistance to balance; in the second, a pair of arms containing resistance only is introduced into the bridge in parallel with the gage arms, so that the best possible balance can be achieved. In adjusting an inductance bridge to balance, it is necessary to adjust both resistance and inductance balances; they are not independent. Both of these methods have been satisfactorily used.*

It should be understood that special provision for making the resistance balance is not required in all installations. If short connecting leads are used, as in station-type gages and comparators, resistance balance is ordinarily achieved through the symmetry of construction of the circuit and its components.

The circuit just described is simple, and employs robust elements which are easily constructed and applied. It is widely used where multi-channel installation is required because of the simplicity of the individual circuits and the versatility of the available gaging elements. For static measurements, 60-cycle current is used for excitation; for dynamic measurements, high-frequency current must be supplied from suitable sources.

Equipment of this sort has wide industrial use. It is used in studies of railroad track: there it has measured the strains and the forces occurring in rails, the slippage in rail joints, the vertical movement of rails and ties, and the strains of deflections in railroad bridges.[105] It has been used on locomotives and on cars, to measure forces, accelerations, strains, and movements.[106, 107] It has been used in oil wells to measure the strains in sucker rods, the forces acting in the pump jacks, and the torque supplied by the motive power.[108] It has been used in naval vessels to measure the strains, forces and movements in the structure, and the power employed in various maneuvers.[109,110] In the manufacture of artillery, such gages are employed to inspect gun-barrels for straightness while they are still hot from the heat-treating furnaces.[111] In routine application in industrial locations, they are used in rolling mills to control roll pressure and to prevent overstress of the mill parts,[112] in cranes to prevent overloads,[113] in profiling and gear-cutting machines to "feel" a pattern and control a cutting tool to produce a duplicate,[114] in steam-turbine generating plants to detect irregularities in operation and to check the performance of all parts.[115] Some generating plants keep permanent records of the changes measured during every start of the turbines.[116] But there are too many uses to list.

*These resistance-balance methods came to the writer's attention in equipment manufactured by the Hathaway Instrument Company.

(104) C. M. Hathaway. Electrical Instruments for Strain Analysis. *Proceedings Society for Experimental Stress Analysis*, Vol. 1, No. 1, 1943, pages 83-93.

(105) Sixth Progress Report of the Special Committee on Stresses in Railroad Track. American Railway Engineering Association, 1933. Chapter 3.

(106) Seventh Progress Report of the Special Committee on Stresses in Railroad Track. American Railway Engineering Association, 1940. Chapter 2.

(107) E. A. Tulus. Tests on Mercury-Arc Portable Substation Car. *Instruments*, Vol. 7, 1934, pages 158-159.

(108) H. E. Dralle and E. H. Lamberger. Oil Well Pumping Tests. *Oil and Gas Journal*, Vol. 40, May 7, 1942, pages 43-44, 46, 48.

(109) H. H. Curry and J. C. Fink. Test of Transient Conditions in Maneuvering a Coast Guard Cutter. *Transactions Society of Naval Architects and Marine Engineers*, Vol. 49, 1941, pages 300-328.

(110) P. D. Gold. Stopping and Backing Trials of a Destroyer. *Journal of American Society of Naval Engineers*, Vol. 53, 1941, pages 76-127.

(111) [Baldwin Locomotive Works.] Haskell Bore-straightness Indicator. *Journal of Scientific Instruments* (London), Vol. 20, 1943, page 148.

(112) M. W. Hively. Use of the Electric Strain Gage. *General Electric Review*, Vol. 44, 1941, pages 621-623.

(113) [General Electric Company.] Crane Stability Indicator. *General Electric Review*, Vol. 47, 1944, page 26.

(114) Anon. Electric Indicator Gage. *Machinery* (London), Vol. 55, 1939, pages 213-217, 241-243.

(115) J. L. Roberts and C. D. Greentree. Turbine Supervisory Instruments and Records. *Transactions American Society of Mechanical Engineers*, Vol. 58, 1936, pages 607-614.

(116) J. L. Roberts and H. M. Dimond. Applications of Turbine-supervisory Instruments to Power-generating Equipment. *Trans-*

Equally efficient for low-frequency operation, and much more compact in construction, a bridge circuit in which all four arms are within the gaging element and are inductively coupled together is effectively used in station-type gages.[117] It is shown in Fig. 53. Such a circuit is not

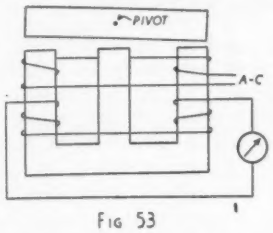

FIG 53

easily made adaptable to general use, and is not easily constructed to allow for a convenient resistance balance. It therefore is most useful in station-type gages, comparators, and the like, in which the gaging element can be installed permanently. Its compactness and efficiency are commendable.

The exciting current can be introduced into a bridge-type electric gaging circuit either conductively, as in the circuit of Fig. 51, or inductively. If the center-tapped inductor in that circuit is replaced by a center-tapped winding of a transformer, the exciting energy can be introduced through another winding on the same transformer core. Alternatively, the bridge output can be taken off.[118] In practice, this expedient is not often used except when it is desired to feed several similar bridge circuits through a single transformer with several similar center-tapped secondary windings. It is an economical method when so used. There is danger, however, of the indication from one bridge circuit being inductively coupled into others through the common supply transformer. This method is best used only when the exciting energy is extremely small and the output of the bridge circuits is amplified before being recorded. Such systems have been effectively applied to the measurement of accelerations and strains in aircraft in flight;[119] for such applications as these conservation of weight and space is extremely important.

Measurements of static conditions can be accomplished with apparatus employing indicating instruments of high current sensitivity, although dynamic measurements require recording instruments which invariably have lower current sensitivities. It therefore is practical to employ bridge circuits in which two resistance arms are used, thereby reducing weight, space and cost. Such a circuit, which has been satisfactorily used with an exciting frequency of 50,000 cycles per second, recording up to over 10,000 cycles, is shown in Fig. 54. Provision for capacity balance as well is required in this circuit, because of the

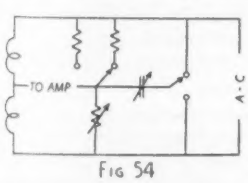

FIG 54

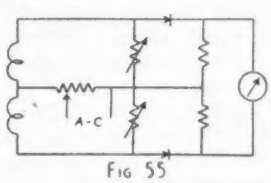

FIG 55

high exciting frequency. The system was used for study of pressure variations and detonation phenomena in airplane motors.[120] A simpler circuit, designed for lower frequency excitation, and not provided with capacity-balance facilities, is shown in Fig. 55.

actions American Society of Mechanical Engineers, Vol. 65, 1943, pages 803-808.

(117) C. M. Hathaway and M. Mohler. Tension Measurement and Control in Cold-Strip Mills. *Electrical Engineering*, Vol. 56, 1937, pages 1141-1144.

(118) M. E. Fiene. Electrical Method of Obtaining Indicator Card of a Compressor. *Refrigerating Engineering*, Vol. 15, 1928, pages 77-80.

(119) H. H. Bruderlin. New Applications of the Variable-reluctance Method. *Instruments*, Vol. 12, 1939, pages 324-326.

(120) J. Ratzke. Ein elektromagnetischer Indikator und Klopfmesser. *Deutsche Luftfahrtforschung Jahrbuch*, 1938, part II, pages 368-372.

The most widely applicable type of bridge circuit for use with variable-inductance (or inductance-ratio) gaging elements is the bridge circuit—either the resistance-inductance bridge if amplification is employed or the bridge with all four arms containing inductance if the current output is to be large without amplification. It seldom is necessary to provide means for making capacitance, resistance and inductance balances; in most instances it is sufficient to make the bridge symmetrical mechanically, and to provide only resistance and inductance balances. The principal function of the resistance balance is to give the two sides of the circuit the same ohmic resistance, while the inductance balance is required to make it possible to adjust the instruments to the proper part of their ranges.

It is a characteristic of the alternating-current bridge that a change in phase of the output current occurs as the bridge is carried through the balance condition. This behavior provides a method of imparting phase-sensitivity—and therefore sensitivity to the direction of the unbalance—to the indicating instrument. If a simple a-c. instrument, sensitive only to magnitude of current or voltage, is used as a detector, the deflection of the indicating instrument is proportional to the magnitude of the unbalance, and does not take into account its direction. But if a phase-sensitive instrument is used, both direction and magnitude are indicated. Electrodynamic ammeters and voltmeters, and all a-c. wattmeters, are phase-sensitive. Most other indicating instruments require the use of a phase-sensitive electric circuit, or the provision of a balancing current to enable them to indicate direction of unbalance. A convenient form of circuit for such applications has been used in a number of commercial instruments;[121] it is a combination of bridge and bucking-type circuit, as shown in Fig. 56. The measuring circuit is a straightforward bridge circuit, and a separate bucking circuit, excited from the same source, is provided to bias the indicating instrument suitably. The bridge is then operated with a small amount of unbalance, at all times, and the bucking circuit brings the indicator back to zero. Changes in the output of the bridge will then appear to have opposite polarities for opposite directions of change in the gaging element.

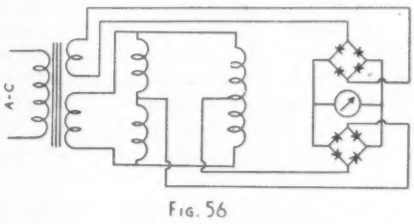

FIG. 56

The selection of the most suitable type of indicating or recording instrument requires consideration of many factors. These instruments, and their associated circuits, will be discussed in detail in a later article.

§8. Phase-responsive Bridge Circuits

In addition to those bridge circuits in which the output of the bridge circuit is utilized simply to determine the presence or the magnitude of unbalance, there is a group of instruments in which the unbalance is applied in such a manner as to restore balance or to operate some indicating or control device. They may be considered phase-responsive, since they employ the phase sensitivity of a circuit to determine the direction of application of the controlling force; in general they will provide their restoring or control forces either through their own exciting current or through an amplifier or servo system.

A basic type of position-repeating bridge circuit—and one of the oldest—is the inductance balance. It is an equal-arm bridge circuit, comprising two inductance-ratio type pick-ups. Its operation depends upon the fact that a magnetic force is exerted upon its core by a solenoid, whether

(Continued on page 414)

(121) M. C. Coffman and C. H. Borneman. Measuring Millionths of an Inch in the Gage Room. *General Electric Review*, Vol. 41, 1938, pages 502-503.

Saving Man-hours in the Industrial-plant Power House Through Instrumentation*

By H. C. CARROLL, Commercial Testing & Engineering Co., Chicago, Illinois

THE modern steam-electric generating plants of public utilities have always taken full advantage of instrumentation to effect economies, both in man-hour operation and in maintenance, as well as taking full advantage of technical advances in the art of power generation, in which they are usually leaders.

It should be borne in mind that in such plants all of their skill, energy, and endeavors are directed to making the final product, electric energy, at the lowest possible cost, which, despite increasing fuel, labor, and material costs, has shown somewhat steady decreases. The incentive to produce low costs in such plants is paramount.

In the power plants of industrial firms, however, where the main products are manufactured goods, the generation of steam and electricity forms but a department (often a vital one), but may represent only a small portion of the total costs entering in the finished products of the plants. Therefore, the incentive for economy and efficiency is not nearly so keen as in the central station field. In some such plants under our observation, the power plant costs represent as low as 10 percent of the total cost in finished products. By reason of the large number of these plants all over the country, the real opportunity for saving man-hours, as well as effecting fuel economies, presents a large field. These are the types of plants we shall discuss.

The fundamental reason for the existence of these plants in industrial firms is the necessity of space heating often combined with the requirements of heat and electric energy for process work. Too often we find that the demands for space heating, being seasonable, do not synchronize with demands of electric energy if generated in the plant, usually by non-condensing engines, with the result that wastes occur. In the larger industrial plants the process requirements of steam may call for pressures ranging from the usual 5 lbs./in.^{2} (which is quite standard for space heating) up to the full designed pressure of the installed steam generating plant. Here the bleeder turbine is applied in obtaining the desired process pressures in connection with electrical generation.

Again, the relationship of electrical load demands and steam demands have to be studied in order to realize the greatest savings in man-hours and fuel. Frequently a combination of purchased power and industrial - plant - generated power is employed to overcome the seasonable operating demands, especially where plant buildings are large. This has provided a solution to the problem of waste in the non-heating season.

In applying instrumentation as a means of cutting man-hours in such plants, some think only of indicating and recording instruments, which indicate and record such functions as temperatures, pressures, and flows, which affect the operatioin of equipment. Actually, however, instrumentation in power plants includes combustion controls, pressure regulators, thermostatic controls, liquid level controls, air controls, concentration controls, and automatized coal and ash handling.

When a plant is small enough to be handled by one day man and one night man, it would seem that there would hardly be the opportunity for saving of man-hours. Yet many such plants, not altogether too small, either, are capable of being so handled, by reason of important functions being automatically controlled, that is, regulation of feedwater heating and boiler level control; feedwater pressure control and automatic boiler feed control; automatic pressure regulation for heating demands; automatic combustion and stoker control; and coal feeding.

It is indeed surprising to find that many plants that burn sufficient coal to warrant installation of stokers and controls are still hand-fired and hand-controlled in every respect, having no instruments except the steam pressure gage which is required by law. In such cases instrumentation would make a large contribution to man-hour and coal conservation.

There often is a great reluctance on the part of the plant management to spend money on boilers that are (or soon will be) old enough to be reduced in pressure, when it is doubtful whether new boilers can be obtained in view of priority restrictions which have been imposed during the last three years. Another reason advanced for postponing investments for new power equipment is that even if the present power plant costs of manufacturing firms are high, the same money put into some of the manufacturing processes would produce greater savings than in the power plant. However, the power plant will eventually need a revamping; and when the present emergency is past, many firms will be in a poor position to meet the keen competition that is certain to come; and they will find themselves considerably handicapped. In anticipation of post-war competition, many plants are now having engineering surveys made, and are laying plans to meet future competition.

Another reason why instrumentation is especially needed now in these power plants is the call into the armed services of many skilled plant operators and maintenance men, which has made it necessary to substitute less skilled and untrained personnel. Also, the high wages of war plants have attracted many away from power plants. This throws a heavy responsibility on the remaining few key personnel of the power plants, and if instrumentation and control are lacking, continuous and reliable operation may be jeopardized.

Automatic combustion control and feedwater control enable one skilled operator to successfully operate as many as four large steam generating units; while one or two men on coal- and ash-handling equipment, properly installed, can take care of a row of such units.

Instrument boards fully equipped with indicating and recording instruments not only enable the operator to be properly guided in successful economical operation, but also furnish 24-hour records for making up permanent records or for further analysis.

Continuous blowndown control is another item that reduces man-hours in the boiler room.

In the larger plants motor-driven line valves enable the operator to cut boilers in and out from a single point of operation, or to control distribution of steam.

Indicating and recording smoke devices keep a constant watch on violations, with alarms to notify the operator when density is too great.

Automatic over-fire air control is now to be obtained by means of the electric eye used on the smoke indicator, which operates a relay controlling the over-fire air fan.

On some of the modern steam generating units, boiler water level at high elevations can be brought down accurately to eye-level for indicating level and recording level on 24-hour charts.

Even the automatic control of water conditioning for makeup purposes can now be obtained.

The proper selection, type, installation, and extent of such controls in application to power plants to accomplish the desired results. both in labor-saving and economy, should be made only after careful study and a survey of each individual plant.

Conditions of operations, characteristics of load, and services to be rendered vary so greatly in power plants that it would be most difficult to give anything but general suggestions for guidance in such application.

For coal- and ash-handling application, the rather expensive automatic apparatus is only warranted where the quantity handled is sufficiently large to save labor, provide storage, or where the design of layout is such as to make

(Continued on page 436)

*Presented at the Chicago War Production Conference, March 30, 1944.

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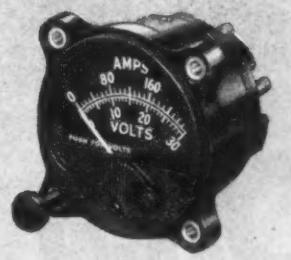

Type DW-53 d-c voltmeters, ammeters, and volt-ammeters that are specially designed to measure voltage and current in battery and battery-charging circuits on naval aircraft. They meet applicable Navy specifications.

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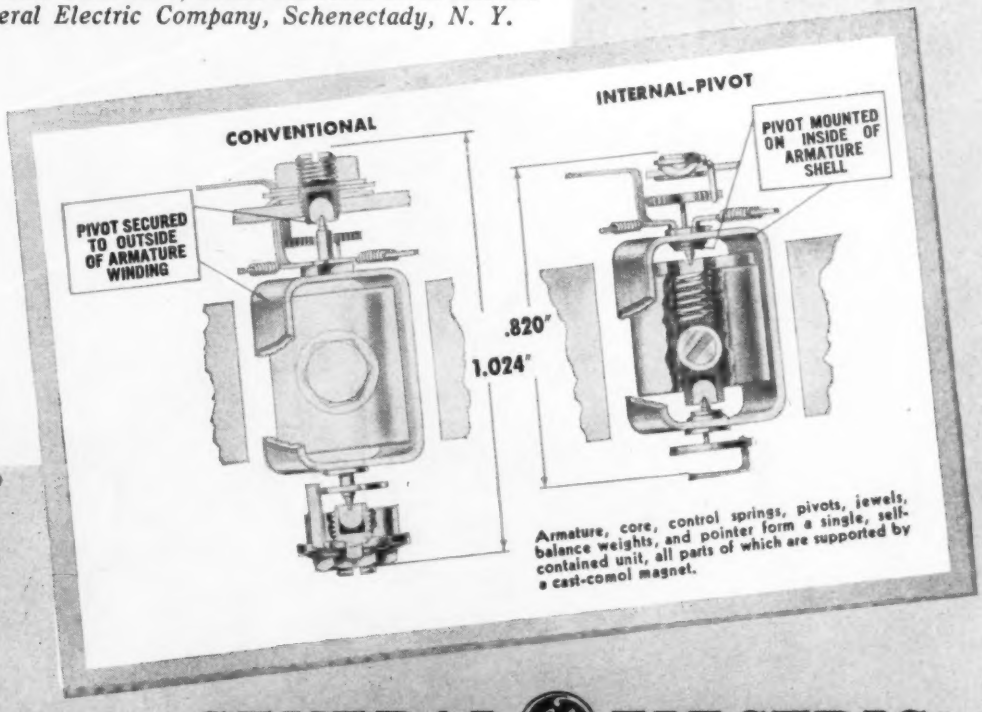
For ratings, price, and dimensions, ask our nearest office for Bulletin GEA-4064, which covers instruments for radio and other communications equipment; or Bulletin GEA-4117, which describes those suitable for naval aircraft. *General Electric Company, Schenectady, N. Y.*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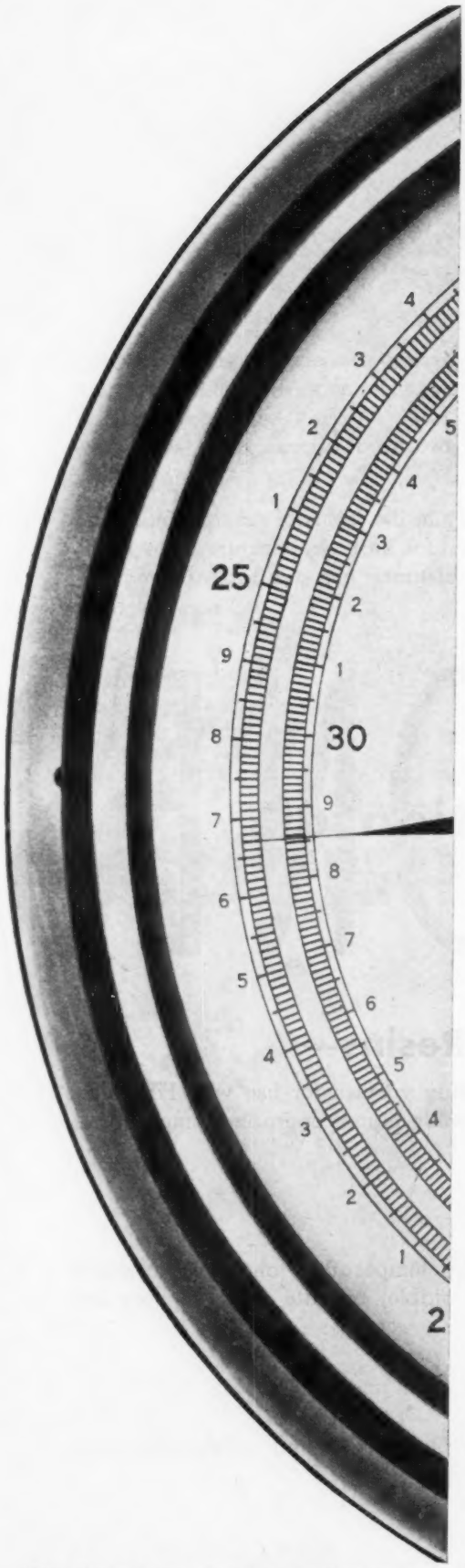

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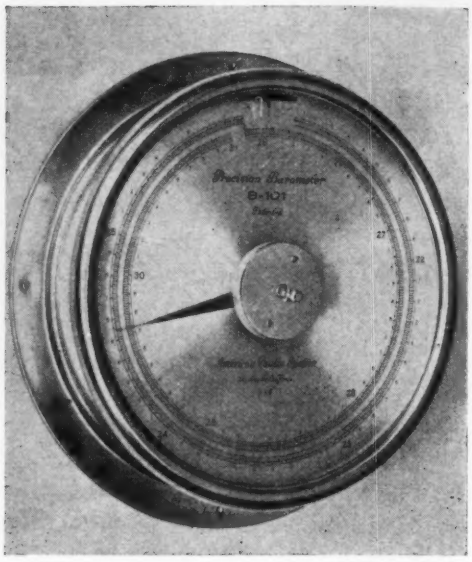

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Communication Flight-testing Production Instrument-testing

Vol. III, No. 7 M. F. Behar, Editor July 1944

Balancing the Vertical and Gimbal Ring Assembly of the Sperry Directional Gyro Indicator

By GEO. R. FORD (with Armed Forces overseas)

THE system explained below, originated by me, applies to all instruments of this model regardless of whether the position of the weights, necessary to effect a balance, forms a near quadrangle or a triangle.

In the event that the Vertical and Gimbal Ring assembly has a near balance, the logical position of the weights in order to effect a balance, would be on or near the 45, 135, 225 and 315 degree points. Therefore, in order to facilitate explanation, the weight nearest one of the above-mentioned points is hereinafter designated by that number, regardless of its true position.

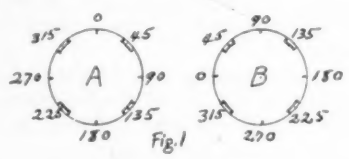

Fig. 1

For the purpose of study, we shall assume the dial represented in Fig. 1, both A and B, to be in balance. Shifting weights 315 and 135 each an equal distance clockwise or counterclockwise would not alter the balance in either A or B. The same is true in regard to 45 and 225. Forty-five shifted clockwise and 315 shifted counterclockwise an equal distance would not alter the balance in A but would destroy the balance in B. In order to retain the balance in B, 225 and 135 must be shifted to conform with the shifts of 315 and 45.

Inasmuch as unbalance is the result of unequal distribution of weight, a balance of vertical ring is effected by shifting weight from the heavier arc of the dial to the lighter arc. Many corrections may be made by at least two distinct shifts. The shifts should be selected with the view of retaining the weights as near their logical position as possible.

EXAMPLES OF UNBALANCE AND CORRECTIONS.

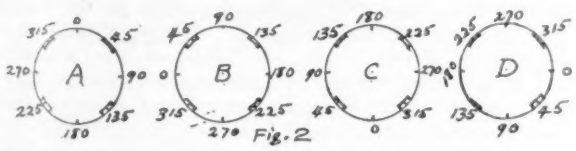

Fig. 2

Fig. 2—1. A: Clockwise drift.
B: Balance.
C: Counterclockwise drift.
D: Balance.
Cor: 45 counterclockwise shift.
135 clockwise shift.
or
315 counterclockwise shift.
225 clockwise shift.

In the event that the drift is strong, the better correction would be to shift the four weights:
315 & 45 counterclockwise.
135 & 225 clockwise.

Fig. 2—2. A: Clockwise drift.
B: do.
C: Counterclockwise drift.
D: do.
Cor: 45 counterclockwise shift.
225 clockwise shift.

2—3. A: Clockwise drift.
BC&D: Balance.
Cor: 315 & 45 counterclockwise shift.

2—4. A&B: Clockwise drift.
C&D: Balance.
Cor: 45 counterclockwise shift.

Those without actual experience in balancing the assembly will likely condemn Nos. 3 and 4. However, due to mechanical defects in construction, they are found and corrected as stated.

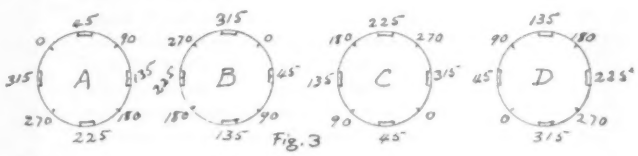

Fig. 3

Fig. 3—1. A: Clockwise drift.
B: Balance.
C: Counterclockwise drift.
D: Balance.
Cor: 45 counterclockwise shift.
225 clockwise shift.

Fig. 3—2. A: Clockwise drift.
BC&D: Balance.
Cor: 45 counterclockwise shift.

3—3. A: Clockwise drift.
B: do.
C&D: Balance.
Cor: 45 Counterclockwise shift.
135 Clockwise shift.
or
225 Clockwise shift.
315 Counterclockwise shift.

To balance the vertical and gimbal ring assembly, place the fixture directly in front with the bottom bearing toward you. The dial may be turned in either direction or

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rocked back and forth at will. A four-point balance of headings shown in Fig. 2 should be made first. In the beginning the drift is usually strong, obviating the necessity of testing on more than two headings. These headings should be 90 degrees apart. In the final stages, the shifts of weights must be determined by the action and inaction of the dial on the four headings considered as a whole.

The bearings should be properly seated. To seat a bearing, turn the dial a degree or two past the heading, then back to the heading, eliminating "back kick." Also hold the dial on the heading and strike the fixture two or three times before releasing.

The starting point is immaterial. Should the 270-degree heading be used, the second should be 90 degrees either way. Rocking the dial from one heading to the other will indicate the shifts necessary to balance both headings simultaneously. Should this be difficult, balance one heading then proceed to the second, third and forth, being governed by examples shown under Fig. 2.

A four-point balance is easily converted into an all-around balance by complying with rules shown under Fig. 3. Few vertical rings are mechanically perfect. The most common error is found in the alignment of the bottom pivot, which often changes the center of gravity during its revolution. These rings cannot be balanced perfectly. However, with the aid of friction (ever-present in ball bearings) a balance apparently perfect may be obtained provided the defects are not too great.

It is important to recheck the balance after the assembly has been installed in its case, by using the following method: Lay the case on its side on a rubber mat with the open end toward you; hold the case with both hands, thumbs in back, raise and lower the open end describing an arc of approximately thirty degrees. In the event the assembly is in balance, it will remain stationary when tested on all headings, provided the motion is uniform. Should the swings be irregular and the irregularity continued, the assembly will revolve slowly and make a complete revolution. A heavier arc will drift downward and remain a little past lower center.

After three or four months' practice, the mechanic should be able to discontinue the use of the balancing fixture and balance the assembly in its case in three to five minutes.

Wire Recorder and Camera Help CAA Check Flight Tests

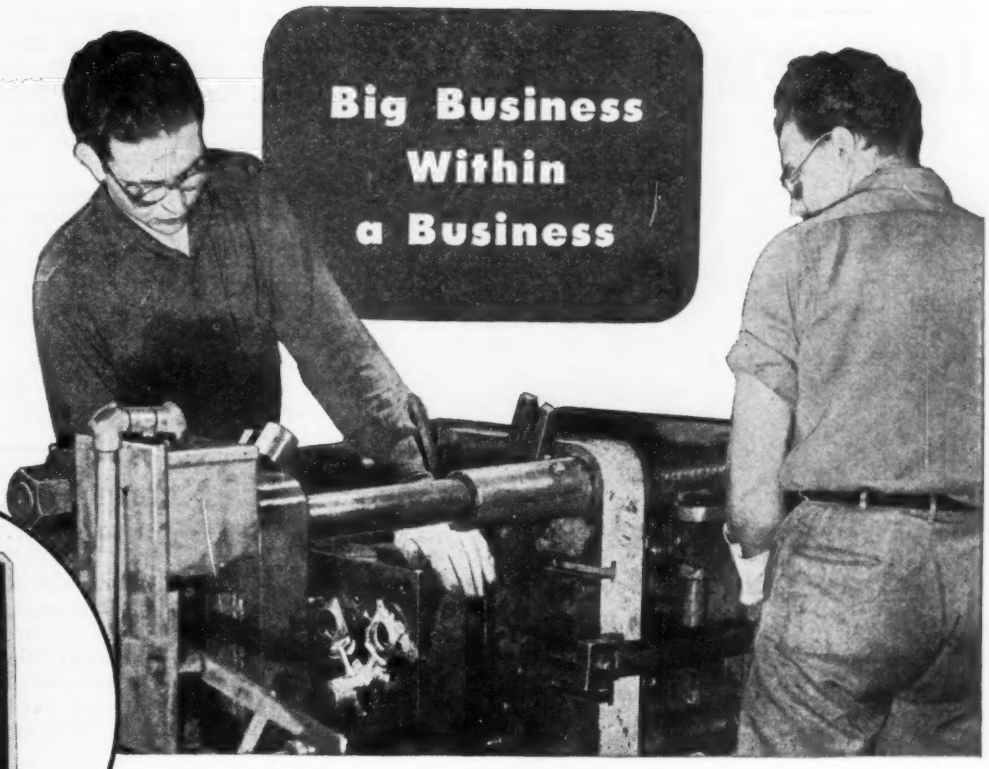
WASHINGTON, D. C., JULY 1—How Civil Aeronautics Administration flight tests, usually conducted tête-à-tête, have acquired an invisible audience in experiments designed to promote greater uniformity in rating, was described here today. The annual meeting of the National Research Council Committee on Selection and Training of Aircraft Pilots was told that the verbal observations of the inspectors are being recorded on a magnetic wire device, while at the same time the performance of the student pilot is photographed by a specially-installed moving picture camera.

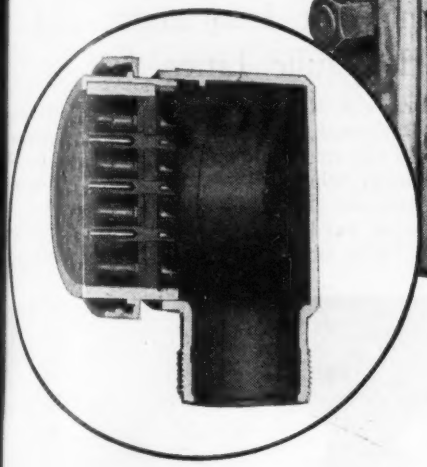
The inspectors' observations, as recorded on the wire and as written on special check sheets, are now being compared with the actual filmed performance of the pilots. The CAA Safety Regulation Service is coöperating fully with this standardization program.

The meeting, held at CAA headquarters in the Department of Commerce, also heard Dr. Morris Viteles of the University of Pennsylvania, chairman of the committee, report on a "hangar-flying" questionnaire which has turned up 300 "tricks" found by instructors to be effective. These are now being evaluated and the best will be published.

Dr. Raymond Franzen, CAA consultant, presented preliminary findings of a study of accident causes he is making in coöperation with Dr. Dean R. Brimhall, CAA Research Director. Ultimate aim is to revise flight instruction methods to place more emphasis on training students to recognize and avoid situations in which accidents occur.

Dr. Robert Y. Walker reported progress of the experimental flight training program at the University of Ten-





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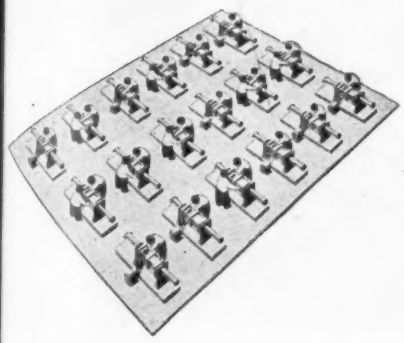

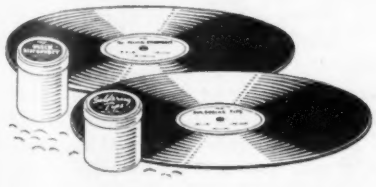

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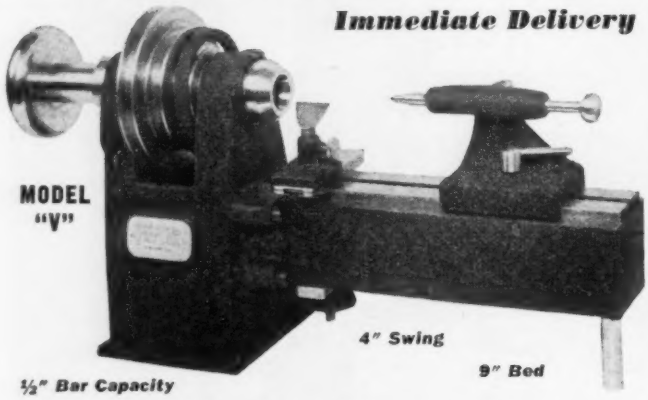

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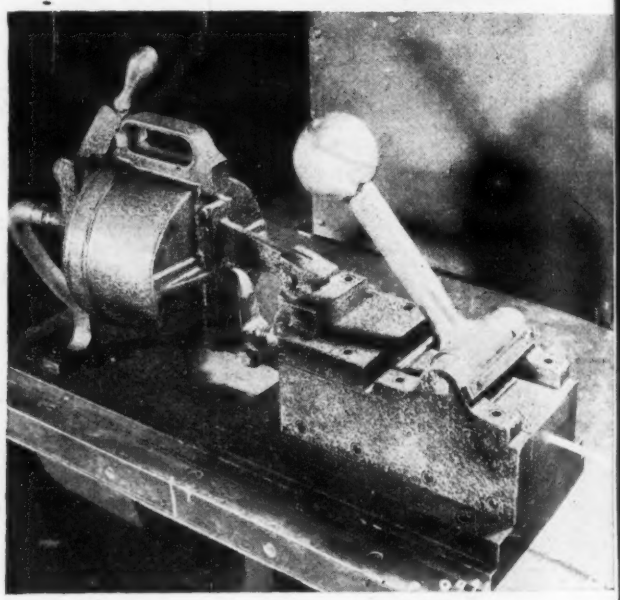
nessee Institute of Aviation Psychology, which he directs. Supported by CAA and state funds, the Institute recently began the training of 20 civilian residents of Knoxville at the University Airport. The courses of instruction differ in the amount of time devoted to teaching particular maneuvers, to determine which pattern makes for acquisition of the greatest flying skill.

Members of the executive subcommittee which has supervised the research projects discussed at the meeting are: Dr. Morris S. Viteles, University of Pennsylvania, chairman; Dr. Dean R. Brimhall, CAA; Dr. Charles Bray, National Defense Research Committee; Cdr. Daniel J. Brimm, Navy Dept.; Dr. Leonard Carmichael, President, Tufts College; Lt. Cdr. Jack Dunlap, Navy Dept.; Lt. Col. John C. Flanagan, War Dept.; Dr. H. M. Johnson, Tulane University; Dr. Walter Miles, Yale University Medical School, and Dr. G. R. Wendt, Wesleyan University.

Bead Former for Instrument and Hydraulic Lines

INVENTED by Frank J. Nickel, repairman at The Glenn L. Martin Co., Baltimore, Md., this tube beading device has effectively solved the small-diameter tube beading problem at that company, where ¼" O.D. tubing is used extensively for instrument, hydraulic and fuel lines.

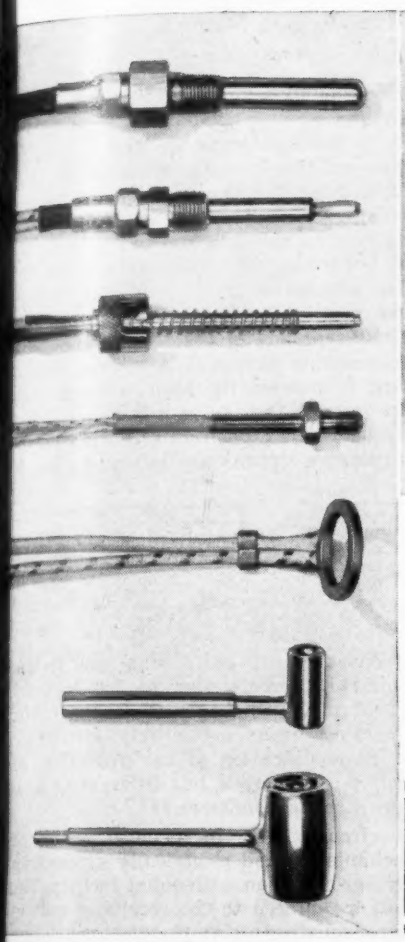
Where conventional beading methods utilize tools by which the bead is rolled into the metal, the new method

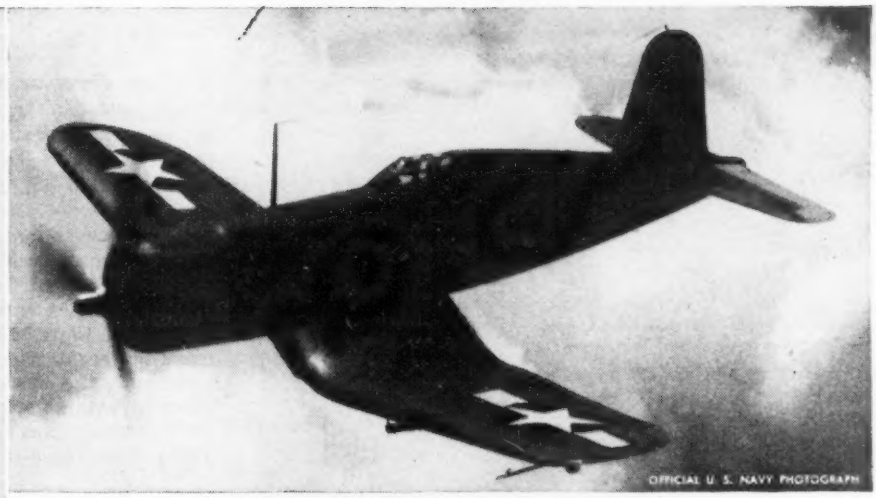


produces the bead by squeezing. The machine consists of a pneumatic squeezer with two sets of blocks cut out for ¼" tubing. One set of blocks is stationary and the other movable. In each set of blocks the ¼" hole is enlarged to a cup shape at one end.

The tube to be beaded is clamped securely in place in the stationary blocks, with the end upon which the bead is to be raised extending out through the cup-shape opening and into the movable blocks where it is likewise clamped. Both sets of blocks are actuated by a cam clamp. After the tubing has been clamped in place, a pneumatic cylinder pushes the movable blocks forward, compressing the tube which expands into the cup-shaped recess to form the bead. The height of the bead is controlled by the movement of the cylinder arm and the size of the cutout in the blocks.

The new method shortens the tube about ⅛" but this can be easily compensated for in the development of the true length. At the same time, the new tool offers a further advantage in that it increases the wall thickness of the tube in the area around the bead, adding to the strength of the bead.





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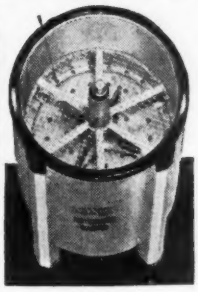

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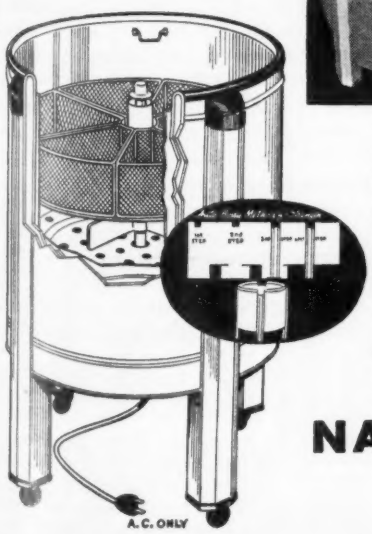

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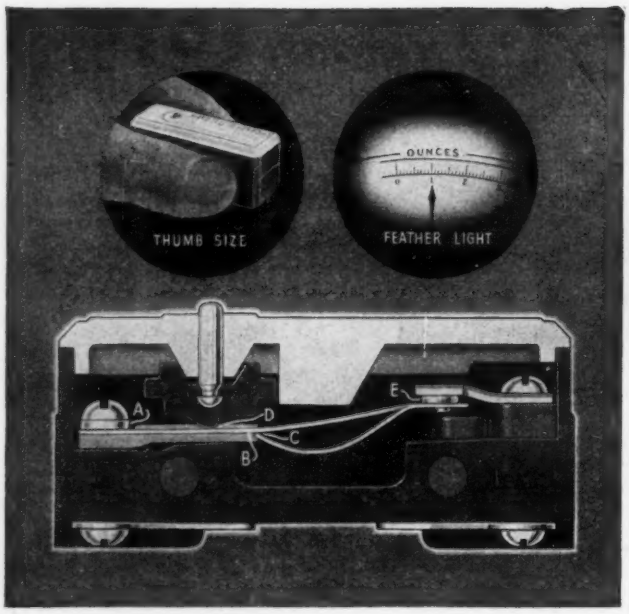

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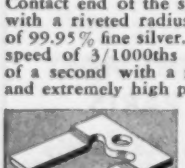
The beryllium-copper spring is made in one piece. It is gauged to an accurate .0085" thickness; has high resistance to fatigue. Ends of compression members are finished to provide an extremely low friction bearing. Contact end of the spring is fitted with a riveted radius type contact of 99.95% fine silver. It moves at a speed of 3/1000ths to 5/1000ths of a second with a rolling action and extremely high pressure.



Short spring members pivot in patented V-grooves of this sturdy brass anchor. Note the special shape of these grooves, which reduces friction to a minimum.

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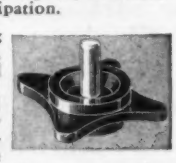

Operating plunger is a highly polished stainless steel pin imbedded in an accurately moulded star-shaped Bakelite head. Provides long over-surface path to live parts, thus insuring freedom from electrical leakage. Plunger head cannot rotate within the housing, insuring against any variation in point of operation.

If you would like to know more about the Micro Switch, send for the two Handbook-Catalogs illustrated here—No. 60, which covers Micro Switches in general; and No. 70 which deals with specific Micro Switches for use in aircraft. © 1942

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Continued from page 403

it is excited by direct or by alernating current. If two inductance-ratio elements are connected as shown in Fig. 57, the current flowing through arms Z_1 and Z_2 will depend upon the position of the iron armature within these two inductive arms; conversely, the position of the iron armature in the receiving element will be controlled by the ratio of the currents flowing through the two coils Z_3 and Z_4—the greater pull being exerted by the coil carrying the greater current. The armature in the receiving element will assume the same position as that in the transmitting element, if there is sufficient power available in the instrument to operate the receiving device. The current required to supply the system is necessarily high; enough power must be available to operate the indicating device against its mechanical resistance. Other position-repeating circuits based upon phase-responsive circuits are in use; in one, for

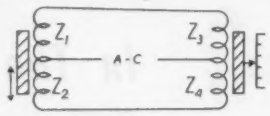


FIG 57

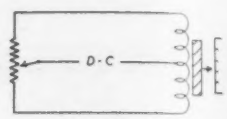


FIG 58

example, which can operate with more than two stations, each element is similar in construction to the induction-type a-c. regulator; here the phase shift of the current flowing in the connecting lines is the only criterion of position. In another (a modification of the preceding) the same operating principle is employed, but different units are employed as receivers and transmitters.[122]

Induction-balance circuits are in general reversible; that is, they are mechanically and electrically symmetrical and will operate in either direction with equal facility. Thus the mechanical resistance offered to the receiving unit will appear also at the transmitting unit; the electrical system simply acts as a transmitting medium. An amplifying system can be installed between the two elements; then the power to actuate the receiver will be supplied by the amplifier, and no drag will be imposed on the transmitter. The amplifier may be electronic, a servo system, or any other suitable form.

A simpler form of control, not employing amplification but offering no mechanical reaction at the transmitter, is afforded by a bridge circuit in which two arms are resistive, and two inductive, as in Fig. 58. The action of the circuit is just as in the true induction balance, except that the resistance unit must be used as the transmitter, and the inductive unit as the receiver.[123] The currents through the resistance unit do not act to alter its adjustment, so that the only force required to operate the system is that needed to move the slider of the resistance unit. The system is not reversible. It is especially applicable to handling relatively large power through the operation of electric contacts by the moving armature, the primary element being a small voltage-dividing resistor at some remote point.

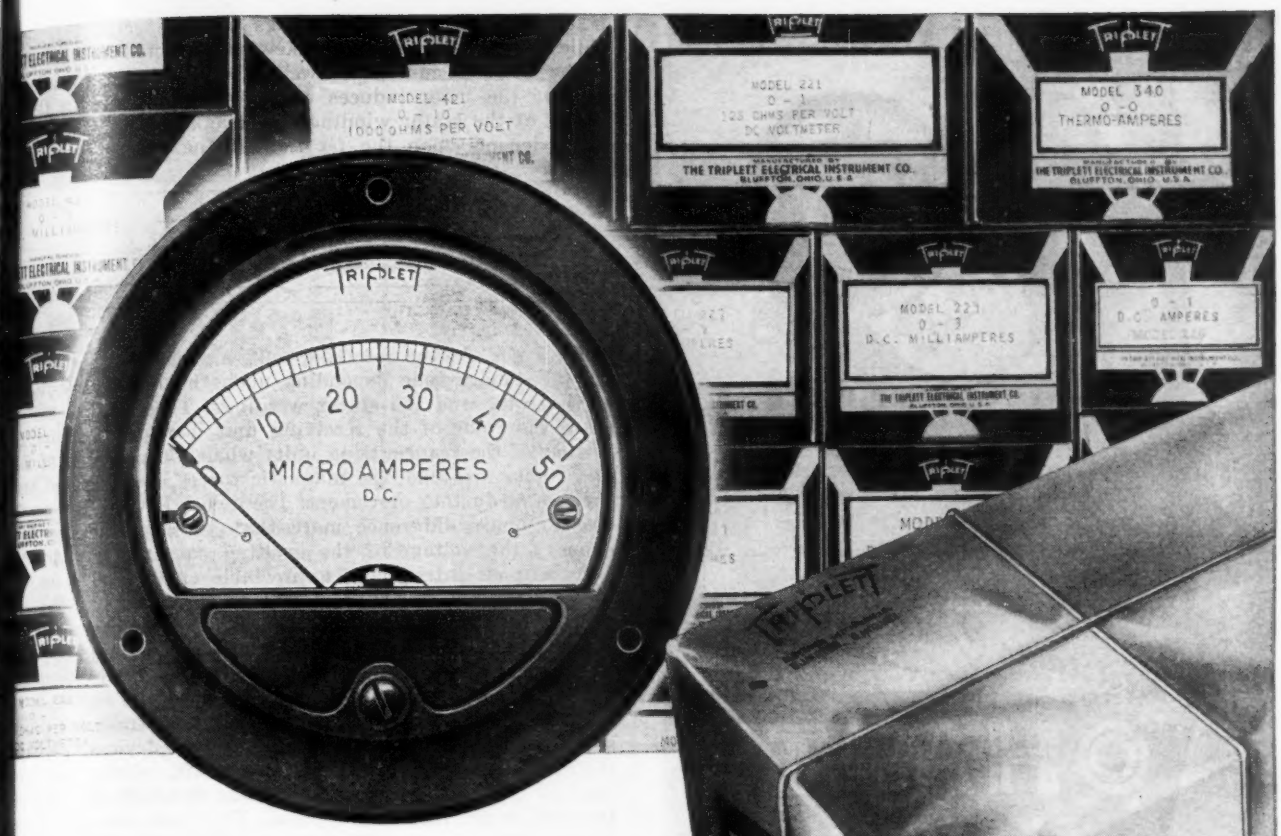
The Kelvin and other current balances, and other telemetering and control circuits employing this principle are in wide use, but are described in detail elsewhere.[122]

Systems for position-repeating depending upon the phase control of an electrical element are in extensive use. These are based on the self-synchronizing-type motor—known by the trade names of Selsyn, Autosyn, Telegon, etc.[122,124] They are phase-responsive devices; in construction each unit is an a-c. motor having a three-phase stator and a two-pole rotor. The most common connection is that shown

(122) P. A. Borden and M. F. Behar. Telemetering and Totalizing. *Instruments*, Vol. 8, Sept. 1935, pages 235-240, Dec. 1935, pages 323-332.

(123) [Minneapolis-Honeywell Regulator Co.] Proportioning Electric Motor Control System. *Instruments*, Vol. 5, 1932, pages 24-25.

(124) W. A. Reichel and R. C. Sylvander. Autosyn Application for Remote Indication of Aircraft Instruments. *Journal of the Aeronautical Sciences*, Vol. 6, 1939, pages 464-467.



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in Fig. 59; the stator windings are connected together while the rotor windings are likewise connected together and to the exciting current as well. The alternating magnetic field of the rotor induces currents in each of the three phases of the stator winding; the magnitudes of these currents depend upon the position of the windings relative

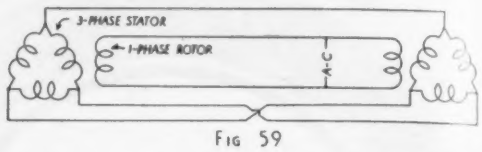

FIG 59

to the rotor. At the receiving unit, magnetic forces are set up, their magnitude depending upon the relative positions of the rotor and the stator windings. These forces act to place the rotor of the receiving unit in a position similar to that of the transmitting unit; when the positions of the two rotors are alike the magnetic forces are balanced and there is no further movement. The device is therefore sensitive to phase difference more than to magnitude or frequency; the voltage of the exciting current can vary by 10% without introducing appreciable error. The device is not well suited to precision gaging, because, like the induction balance, the resistance encountered at the receiving element is transmitted back to the transmitter, and appears as a drag on the primary element. (In some applications this is an advantage because it enables the operator to "feel" the action of the device he is controlling.) Such systems are extremely useful as indicating devices; perhaps their most appealing use is in aircraft, where they are used to transmit position indications from all quarters of the ship to an instrument panel. They are actuated there by all sorts of primary elements—they indicate positions of landing gears, amounts of fuel in gasoline tanks, etc.

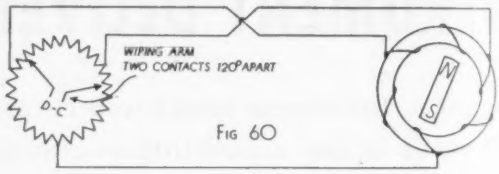

FIG 60

Another basic type of position-indicating device must be listed here; it is the so-called "d-c. selsyn" which employs a resistance-type transmitter and a reluctance-type receiver, as shown in Fig. 60.[125] The transmitting unit is a resistance element distributed around an entire circle; the receiving element is a ring or Gramme-type winding also distributed around an entire circle. The moving arm of the resistance element causes a current pattern to be set up in the interconnecting leads and the receiving unit; the currents flowing in the receiving unit set up a magnetic pattern there which causes the magnetized pointer to assume a position similar to that of the moving arm of the transmitter. This device is also a position indicator, but its action is not reversible. (Compare to Fig. 56.)

Many other devices of this type are available, but, although their sphere of use is very wide, they hardly fall within the scope of a work dealing with gaging methods, and will not therefore be discussed.

§9. Magnetic Circuits

In magnetic thickness (or quality) gages, and in eddy-current methods of inspection, the operating principle depends upon the establishment of magnetic or eddy-current patterns within the material being examined. The criterion of quality then employed is the character of the pattern; if it is uniform, the material is uniform; if its intensity is equal to that in a standard sample, then the material is like that of the standard sample. But for efficient operation of these methods, the magnetic field patterns, or the eddy-current patterns, must be established in a favorable man-

(125) C. F. Savage. Aircraft Instruments. *General Electric Review*, Vol. 45, 1942, pages 495-498.

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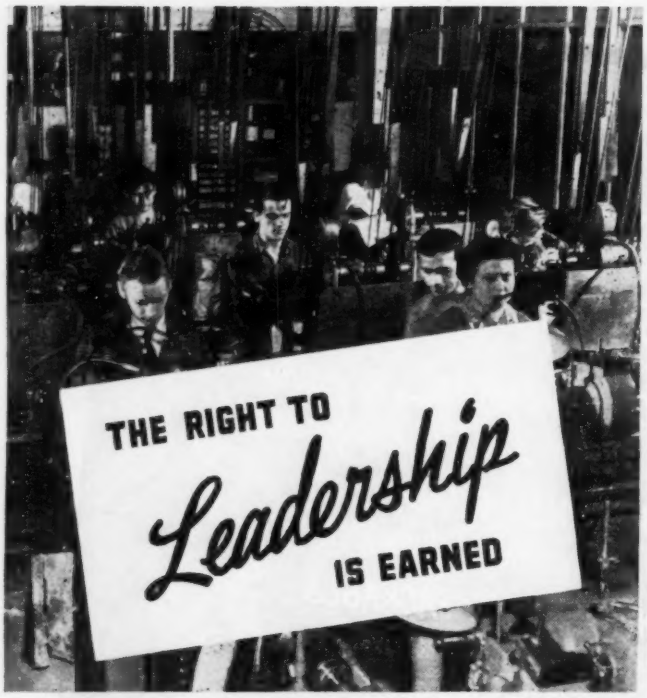

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ner. Consideration must therefore be given to the magnetic circuits employed in such methods.

Perhaps the simplest of these magnetic circuits is that of the plate-thickness gage of Fig. 44. Here a source of magnetomotive force, represented in the figure as a permanent magnet, is placed in a magnetic circuit which contains two parallel magnetic paths, between which the total flux divides in inverse proportion to their reluctance. In one of the plate-thickness gage of Fig. 44. Here a source of these paths is placed an instrument which measures the flux passing through that path; in the other circuit is placed the material being examined. Fig. 61A shows this

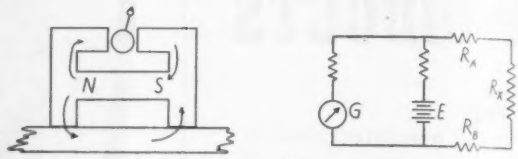

FIG 61

magnetic circuit, with the paths taken by the magnetic flux indicated by arrows. Fig. 61B shows its electrical analogue. In the analogue, the source of energy is the battery, E; the paths through which the current flows are resistors; the instrument is a current-sensitive instrument; the magnetic reluctance of the specimen is represented in the analogue by a resistance, R_X. In series with R_X are two resistances R_A and R_B. They represent the magnetic reluctance of the two air-gaps which occur at the points of contact of the gaging device with the specimen. In this circuit, if a change in R_X is to be indicated by an indication on the instrument G, it is necessary for accuracy that the resistances R_A and R_B be kept small, and as nearly as possible constant. In the magnetic circuit, the employment of large areas and short air-gaps will accomplish the desired result. Over a certain range, then, the reluctance of the specimen will be indicated by the deflection of the flux-density meter. If the reluctance of the specimen grows very small, there will be only a small proportion of the magnetic flux in the meter circuit, and the accuracy of the method will become small.

In the thickness-measuring pick-ups depending upon the reluctance of the specimen in an a-c.-excited magnetic circuit, exactly the same reasoning applies. It is for this reason that these devices often have pointed feet on which they are placed for operation, and why it is desirable that they be firmly pressed against the specimen.

The use of the specimen, or a part of it, in a magnetic circuit makes possible certain measurements by devices which do not require attachment to the specimen itself. Measurements of the vibration of a machine part can be made by allowing the machine itself to act as the armature in an element like those described here. If the metal of the machine is non-magnetic, it can become part of an eddy-current element. Measurement of the vibration of turbine blades has been so accomplished;[126] in these delicately-balanced devices it is not desirable to attach gage parts. In other applications the desirability may be more of convenience than necessity; in the measurement of eccentricity of a rotating shaft it is convenient to measure to the surface of the shaft rather than to risk attaching any part which might itself affect the eccentricity.[85]

The most useful and most interesting of the magnetic circuits are those encountered in the variable-reluctance gaging elements, and in the gaging systems in which the magnetic circuit includes the specimen. Only a few can be considered here.

The analysis of the magnetic circuit of Fig. 42A, for example, is simple. Here a magnetic field is established, and by proper shaping of the pole-pieces is made uniform. Within this magnetic field a coil is placed; as the coil is moved it cuts some of the flux-lines and, through the process

(126) A. V. Mershon. Vibration Recorder for Electrically Measuring and Recording Small Mechanical Movements. *Transactions American Institute of Electrical Engineers*, Vol. 45, 1926, pages 1007-1012.

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of electromagnetic induction, a voltage is induced in the coil, and a current flows through the circuit of which the coil is a part. The voltage is proportional to the rate at which the flux lines are cut—to the velocity of motion. The device is relatively efficient; most of the energy introduced mechanically appears as electric energy in the coil. This instrument is used to convert mechanical energy to electrical—as a detector of acoustic waves, as a pick-up for vibrations,[127,128] as a device for detecting the roughness of a surface,[129] or for any other application in which a velocity over a small distance is to be measured. Or it can convert electric energy to mechanical—in its use as a loudspeaker, or a unit for vibrating specimens in the testing.[128,130] But its response in all cases is one of velocity.

The moving armature form of the reluctance-type pick-up employs an iron armature which is so mounted that its motion changes the reluctance of the magnetic circuit within the device. Since a coil surrounds a portion of this magnetic circuit, any change in flux through the coil will induce a voltage—it is, again, proportional to the rate of change of flux, or to the velocity of the motion. In the same manner as indicated in Fig. 2C, the sensitivity of the device will vary if the air-gap is changed, growing less as the air-gap becomes greater.

The push-pull form of this pick-up employs two magnetic circuits; the reluctance of one is decreased as that of the other is increased. When the armature is in its central position there is no effective magnetic flux through it, since the fields of the two magnets counteract there. But as the armature moves, one field will predominate as the reluctance of one circuit is decreased; the result is that the magnetic flux through the armature, and the voltage induced in the coil, will vary in direction and in magnitude with the motion of the armature. Over a portion of the range of available motion of the armature, the sensitivity will not vary with the armature position; the result is that the mechanical motion is faithfully represented by the induced voltage. Because of this, the device is capable of measuring vibratory stresses without being disturbed by the slowly-acting strains due to temperature changes. In certain applications—as in the study of propeller vibration—this is a most useful ability. The form of Fig. 42D is similar to that of Fig. 42C except that it is mechanically suited to rotatory displacements.

In the device illustrated in Fig. 43A similar reasoning can be applied; in this pick-up rotary motion, however, will cause no change in the reluctance of the magnetic circuit, while radial displacement will cause such a change. In balancing small motors, therefore, the exact rate of rotation is immaterial, so long as it is high. Further, the angular position of the unbalance can be detected by adjustment of the device to maximum output. Since nothing is attached to the rotor, there is no increase of unbalance.

Gaging elements in which current is induced in a plate or mass of metal, instead of in a coil, are called eddy-current types, because the currents circulate through the plate without being confined to any definite path by the shape of the conducting material. In these units there is considerable loss of energy as heat; the efficiency is low.

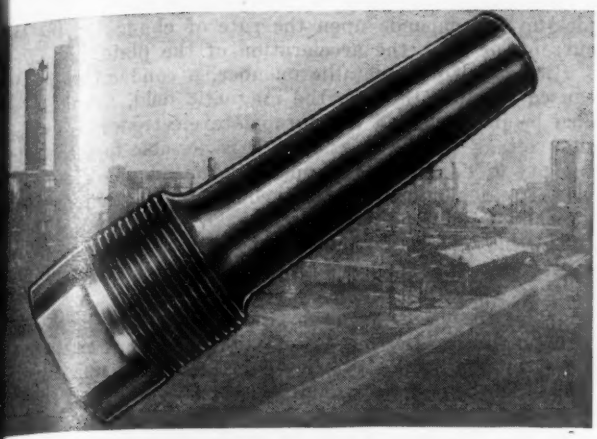
In the element of Fig. 43B, for example, a moving plate in a magnetic field has voltage induced within it, in conformity with the law of magnetic induction. Because of the presence of the voltage, current will flow, and this current produces a magnetic field just as would any other. The induced voltage depends upon the strength of the magnetic field and the velocity of motion; the resulting eddy current depends also upon the resistance of the material of the moving plate. And the voltage induced in the

(127) F. C. Rushing. A Rapid Method for Determining and Correcting Unbalance. *Instruments*, Vol. 8, 1935, pages 228-231.

(128) R. P. Kroon. Mechanical Tests on Turbine Blades. *Instruments*, Vol. 8, 1936, pages 154-155, 159.

(129) E. G. Abbott. The Profilometer. *Mechanical Engineering*, Vol. 60, 1938, pages 205-216.

(130) Forrest Dorman. Electronic Vibration Tester. *Radio News (Radio-Electronic Engineering)*, Vol. 2, June 1944, pages 30-36, 45, 46.



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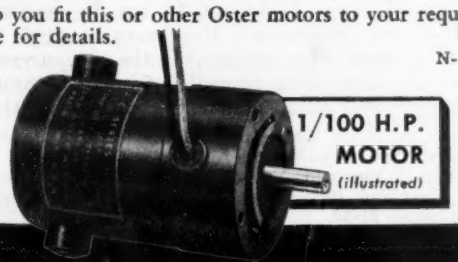

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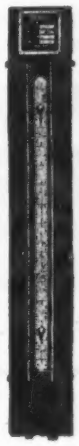

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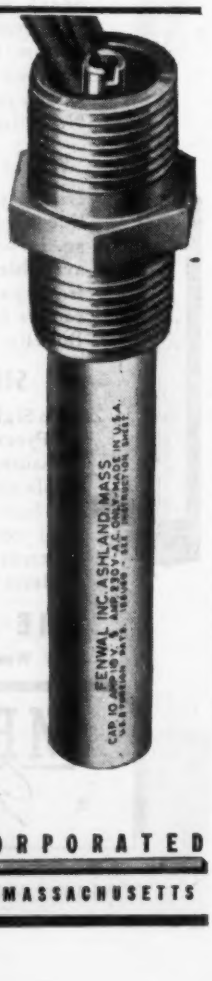

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pick-up coil depends upon the rate of change of the eddy current, or upon the acceleration of the plate.

If, instead of a metallic member, a conducting liquid is caused to move through the magnetic field, a voltage will also be induced, and if appropriate electrodes are present this voltage will be measured; it is possible to measure the velocity of flow in this manner.[131] Indeed, for the study of velocity in small areas of turbulent flow, this method is almost the only one possible.

The eddy currents induced in the plate of Fig. 43B depend upon the strength of the field and the velocity of motion. They depend also upon the resistance of the material of the plate—in accordance with Ohm's law, so that if a portion of the plate were of a different material, or were thinner, its resistance would be higher, and the magnitude of the current would be less; the indicated acceleration would of course be less, too. If the velocity were known then, the apparent change in acceleration would represent a change in the characteristics of the material. It is on this basis that the eddy-current methods of material inspection operate.

In the example described, two elements were present—a magnetic field of constant intensity, and a constant velocity. Both are necessary, to provide the *rate-of-change* action. But both can be supplied in one action, if the magnetic field is changing at a known rate; an a-c. magnetic field will induce in the material eddy currents proportional to the resistance of the material, and a small pick-up coil will have induced in it a voltage inversely proportional to that resistance.

The methods in use employ both systems; some employ steady excitation and a moving measuring element, and some employ alternating excitation and stationary (or moving) measuring elements. A method of inspecting welded seams, for example, consists of weakly magnetizing the material, then passing over the seam a small pick-up coil within which a soft iron armature rotates.[132] The output of the pick-up is constant until a discontinuity is encountered.

Since it is always the *change* in magnetic flux passing through a coil which induces current within that coil, an obvious method for inspecting metallic sheets, for example, consists of passing through the sheet from edge to edge a current of electricity, and passing over the sheet a pick-up coil. When any discontinuity in the sheet current is encountered there will be an indication in the output current of the pick-up. A widely-used method of inspecting railroad rail *in situ* consists of passing a heavy current through a section of rail under the test car, and scanning the rail with pick-up coils.[133] The current is introduced through brush contacts, and so is not constant; the variations in exciting current are prevented from affecting the output by the use of a series-opposition circuit in the pick-up head. Only differences between the two parts of the pick-up structure are indicated.

Discontinuities in the magnetic pattern set up in a metallic part can be detected by applying a magnetic powder to the surface; it will tend to collect at discontinuities.

There are many excellent methods of making examinations of material through magnetic or electric methods; they are based upon the principles outlined here.

The elementary principle of recording the pulse of current produced when a permanent magnet passes near a coil of wire has been put to use in several measuring methods. As illustrations, these may be cited: the measurement of speed of a runner,[134] the measurement of speed of an airplane being propelled from a catapult launching device,[135] and as a tachometric device. In the latter, the

(131) A. Kolin, Electromagnetic Velometry. *Journal of Applied Physics*, Vol. 15, 1944, pages 150-164.

(132) R. Berthold. Non-Destructive Testing Based on Magnetic and Electrical Principles. *Civil Engineering* (London), Vol. 34, 1939, pages 29-33.

(133) E. A. Sperry. Inductive Tests of Rails and Cables. *Transactions American Society of Steel Treating*, Vol. 16, 1929, pages 771-798.

(134) A. V. Hill. Are Athletes Machines? *Scientific American*, Vol. 137, 1927, pages 124-126.

(135) [General Electric Company.] Speed Indicator for Timing Aircraft Catapults. *Instruments*, Vol. 13, 1940, page 326.

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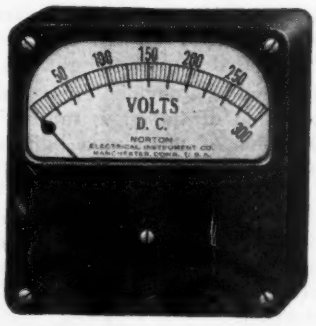

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pulses were produced by an inductor-type a-c. generato and passed through a transformer with an easily-saturat core;[136] each pulse was by that means made of the sa shape and size as every other pulse, and it was possib to count the pulses to arrive at a determination of t rotatory speed.

(136) [General Electric Company.] Electric Tachometer. *struments*, Vol. 8, 1935, page 217.

Electron Tube Principles

Continued from page 397

foregoing paragraphs is a special form of cold-cathode tu but its principle is not greatly different from the small tubes first referred to.

Smaller tubes are also used for the production of lig In the early development of television cold-cathode gl tubes were used as a source of modulated light. The ill mination which these tubes produce is directly proportion to the current and their response to changes in current extremely rapid. Modern television systems use cathod ray tubes to form the received image and so the glow tub are no longer used for this purpose but they have oth applications.

A simple type of cold-cathode tube used for the produ tion of modulated light is shown in Fig. 146. This vie does not show the glass envelope but, as will be noted, consists merely of two parallel plane electrodes, placed close together that the discharge takes place between t outer surfaces rather than the inner ones. Hence, if t spacing is correct the outer surface of the cathode will uniformly covered with glow.

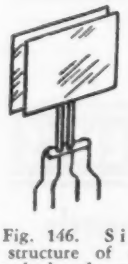

Fig. 146. Simple structure of a cold-cathode tube used for the production of light.

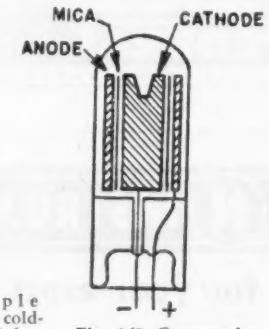

Fig. 147. Cross-section of a crater type glow tube.

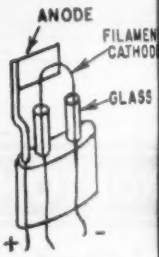

Fig. 148. Modifi form of cold-catho tube used for supp ing modulated lig for sound recordi

Another type of glow tube is shown in Fig. 147. This called the crater tube. The cathode is a solid cylinder whic fits within a thin cylindrical anode and is separated fro the latter by a mica barrier. The end of the cathode has cone-shaped crater. The discharge takes place between t outside of the anode and the cone-shaped crater. The hig current density at the center of the crater results in concentrated source of light.

It should be obvious from what has been said regardin the action of the glow tubes that such tubes used in th production of modulated light should be operated so tha the voltage across the tube will never fall below the poin at which the arc goes out. If the voltage falls below th arc extinction potential, the tube goes out and reignitio will not occur until the voltage has risen to the ignitio potential which is always higher than the extinction po tential. Such interruptions in illumination would result i distortion.

One of the important uses of glow tubes is to supply th modulated light source for sound recording on motion pic ture film. It is evident that the light intensity in this cas will have to follow accurately the variations in sound in tensity. A modified form of cold-cathode glow tube de veloped for this application uses a hot filament as a cathod with a plate anode. The hot filament furnishes a wea source of electrons which reduces the voltage drop but doe not furnish enough electrons to produce an arc. This form of lamp is shown in Fig. 148.

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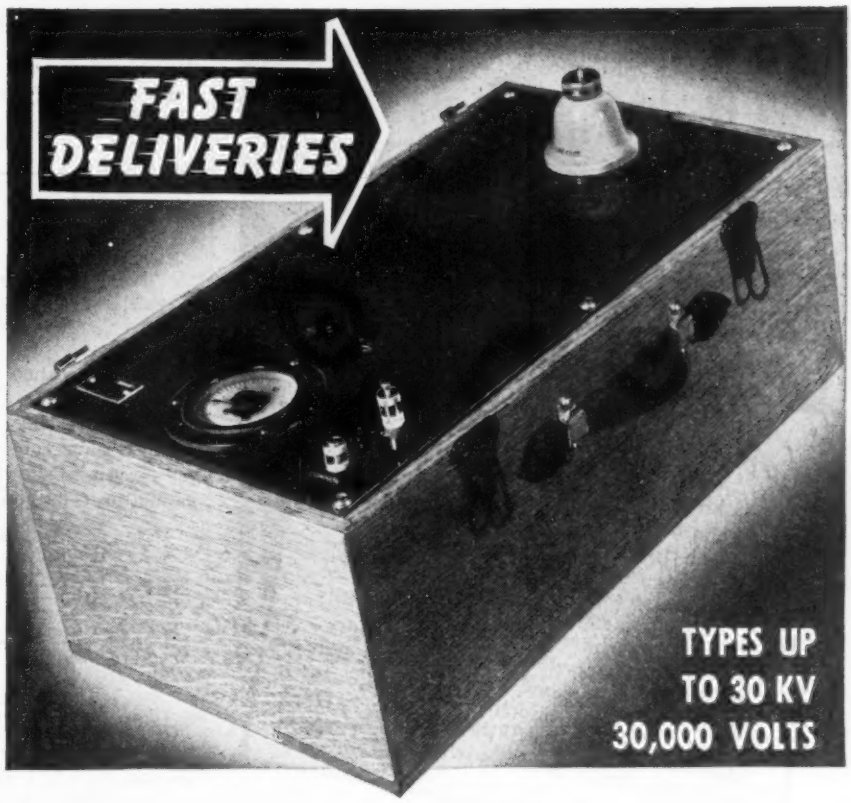

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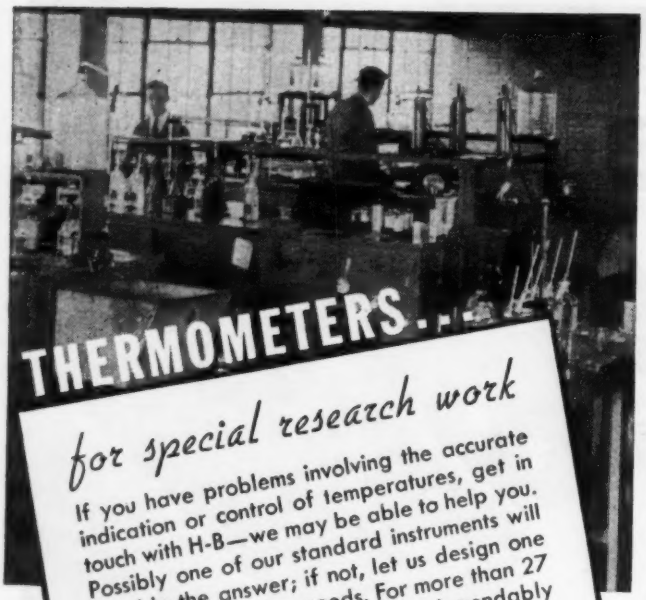
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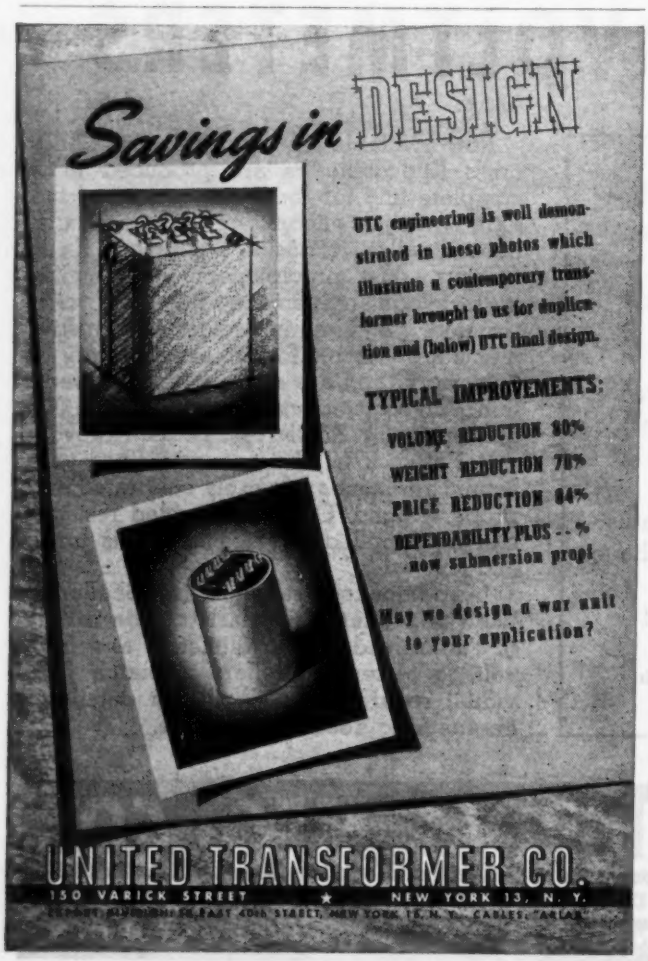
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In using modulated light tubes, it usually is necessary to supply them with power from an electron-tube amplifier. The simplest way is to connect the tube directly into the plate circuit of the power amplifier tube as shown in Fig.

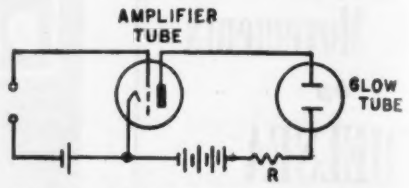

Fig. 149. Amplifier supplying a glow tube.

149. A resistance should be placed in series with the glow tube as shown.

An interesting and very useful application of the cold cathode glow tube is that of a relaxation oscillator. A simple circuit is shown in Fig. 150. A glow tube shunted by a capacitor C is connected to a d-c. power supply through a

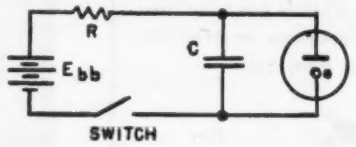

Fig. 150. Simple relaxation oscillator circuit.

high resistance R. Assume that the capacitor is initially uncharged when the switch is closed. The capacitor charges through the high resistance, the voltage rising exponentially according to the following equation:

$$E_c = E_{bb}(1 - \epsilon^{-1/RC}) \quad . \quad . \quad . \quad . \quad . \quad 22\text{-}$$

When the capacitor voltage E_c equals the breakdown voltage of the glow tube, E_d, the capacitor will discharge through the tube. Since the resistance and the inductance of the conductors between the capacitor and the tube is low, the discharge current is high. When the potential across the condenser falls below the extinction potential E_e of the tube, the discharge ceases. Since the discharge current is high the discharge time is extremely small. Once the tube goes out, the capacitor immediately begins to recharge. When the potential across the capacitor again reaches the discharge value E_d, the tube breaks down and the process repeats itself. The process therefore is self-sustaining and

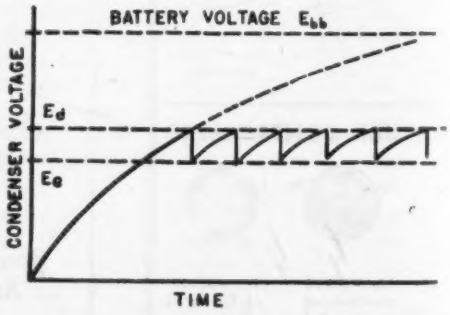

Fig. 151. Graph showing the character of the oscillations produced by the relaxation oscillator circuit.

results in a series of oscillations that have the character of those shown in Fig. 151. The frequency of the oscillations depends almost entirely upon the time taken to charge the capacitor through the resistance R from the extinction potential to the ignition potential. This time increases with the difference between these two potentials and with the capacitance C and the resistance R. It decreases with increase of applied voltage. The wave shape also depends on applied voltage. Using the 874 tube previously referred to (for which E_d equals 125 volts and E_e 90 volts) and with a 600-volt d-c. supply, the wave shape is as shown in Fig. 152(A), a rectangular saw-tooth wave. If this tube is used

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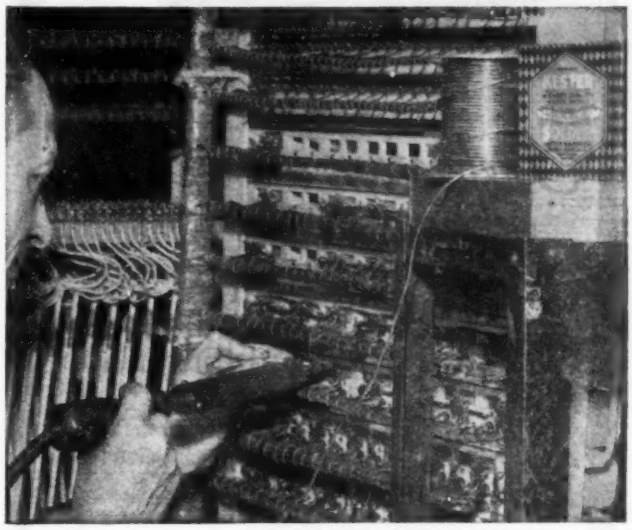

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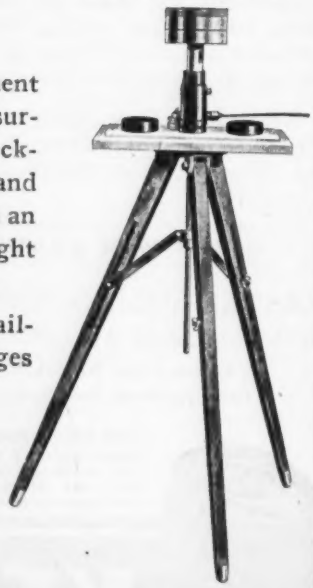

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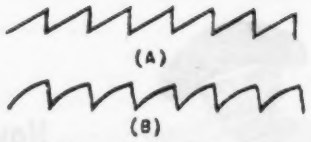


Fig. 152. Types of waves produced by 874 tube in relaxation oscillator circuits.

with a 135-volt supply, however, a curved saw-tooth wa such as in Fig. 152(B) results.

Such relaxation oscillators have a wide range of f quencies. They can be designed to produce frequencies low as 1 cycle every 5 or 10 minutes or as high as 10,0 cycles per second. The latter is in the neighborhood of t upper limit and is obtained usually without a capacit the electrodes and connecting leads providing the necessa capacitance.

Theoretically the lower limit of frequencies produced these oscillators depends largely upon the use of lar enough capacitors but practically difficulties are encou tered when working with very low frequencies (say 1 cy in 15 min.) because of capacitor leakage. Another fact also enters in; because the ignition and breakdown of gl tubes are dependent upon the presence of some initial io the oscillations at low frequencies tend to be irregular u less provision is made to supply a steady source of initi ions. Quite often a small amount of light directed again the cathode will result in sufficient photoelectrons to gi stable operation. The presence of radioactive material al stimulates stable operation. In the absence of light or radi active material, the initial ionization is probably induce by cosmic rays and in this case ionization would not b constant.

Relaxaton oscillators can be locked into step with fr quencies equal to or very nearly equal to the oscillator

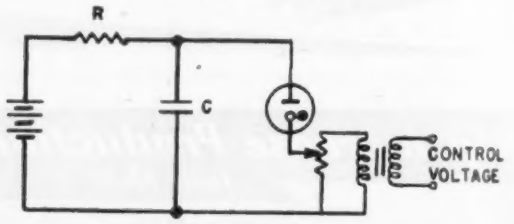


Fig. 153. Circuit showing relaxation oscillator locked in step with another frequency.

to some harmonic or sub-harmonic of that frequency. Whe this is done the control voltage is usually supplied throug a transformer in series with the terminal of the glow tub that is not connected to the resistance. A voltage-dividi resistor serves to adjust the control voltage applied to th tube as shown in Fig. 153.

Theoretically a true triangular saw-tooth wave, such a shown in Fig. 152(A) cannot be obtained from a simpl circuit such as that shown in Fig. 150. Actually the hypot

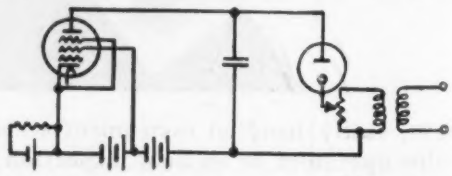
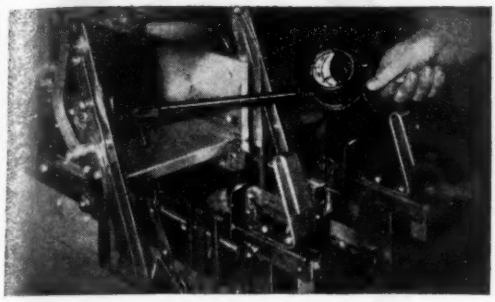


Fig. 154. Circuit using a pentode to supply linear voltage to a relaxation oscillator.

enuse of the triangle in 152(A) is slightly curbed becaus the capacitor charging voltage rises exponentially as shown in Fig. 151. For most practical purposes the slight curva- ture of the hypotenuse is of no importance but if a true triangular saw-tooth wave is needed it can be obtained by circuits which provide a linear charging voltage. Such circuits can be designed by the use of a high-vacuum triode with a positive grid voltage and low filament temperature or better still by the use of a pentode. A circuit of this type is shown in Fig. 154. The plate current of the pentode is practically independent of the plate voltage over a wide



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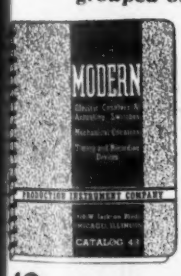

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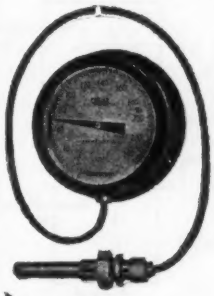

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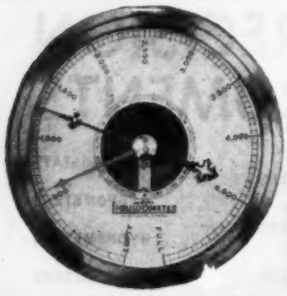

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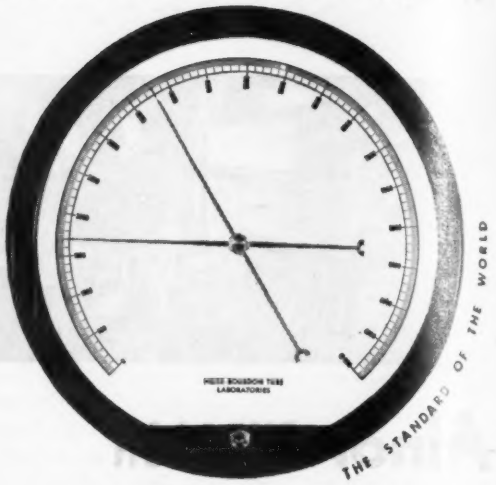

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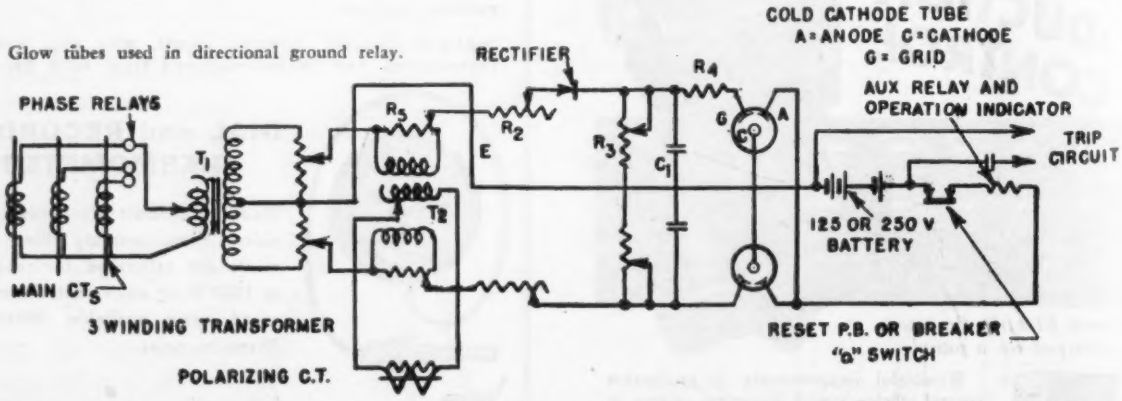
It is not feasible here to show in detail all the types of applications of glow tubes, but enough has been presented here to indicate their general application. They are proving more useful as time goes on and in recent years they have been applied in many commercial circuits. A recent application* is shown in Fig. 155. This circuit shows the connections for a directional ground relay, which operates on the sum of the residual currents from the main and polarizing transformers. If the currents from the main and polarizing transformers are of the same instantaneous polarity, the two resulting secondary potentials will be additive and the relay will operate on the sum of the two potentials, but, if of opposite instantaneous polarity, the two potentials will be subtractive and the difference will not be sufficient to operate the relay.

Fig. 155. Glow tubes used in directional ground relay.



From what has been written here, it will be evident that cold-cathode tubes comprise a wide variety of forms, sizes and uses. As light sources they vary all the way from the long tubular neon sign lamps used to light up our cities to the tenth-of-a-watt test lamp used for circuit testing. As control devices they are very flexible, require little or no care and are highly reliable. They do not take the place of thermionic tubes but in combination with thermionic tubes they extend their use. They are extremely useful and interesting devices.

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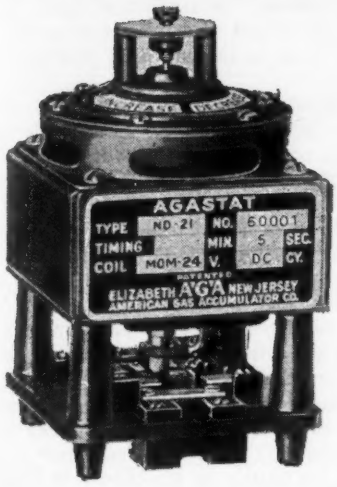

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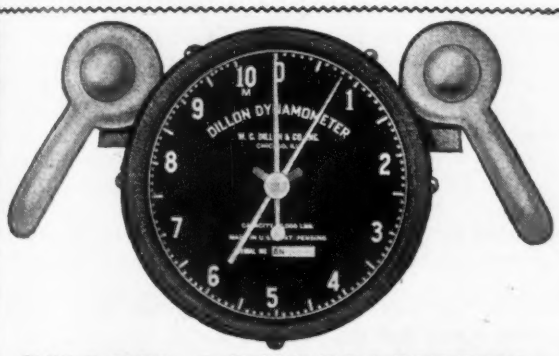

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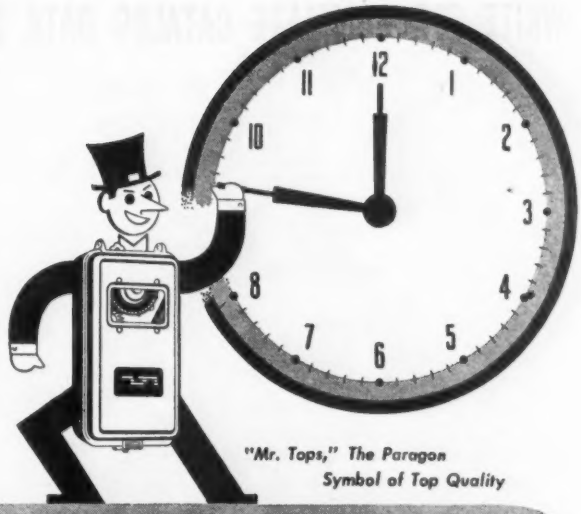

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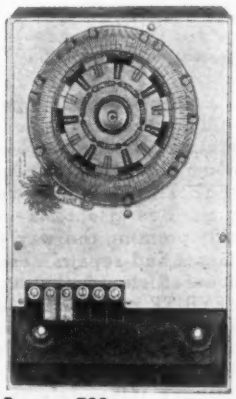
Paragon 700 Series Time Switches are equipped with 6" calendar dials which make one complete revolution every 7 days. Dial trippers can be independently set for different daily ON and OFF schedules. Settings can be made in advance for an entire week. Any day or days operations may be omitted entirely on a pre-set program.

Each day of week clearly separated from other days; graduated into hours and half hours; day and night distinctly separated. Operations from ON to OFF or from OFF to ON can be set as close as three hours apart and can be separately adjusted throughout each 24 hour day in the week.

Write for a complete bulletin.



Paragon 700 Series Time Switch

PARAGON ELECTRIC COMPANY

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BUILDERS OF ELECTRICAL EQUIPMENT . . . SINCE 1905

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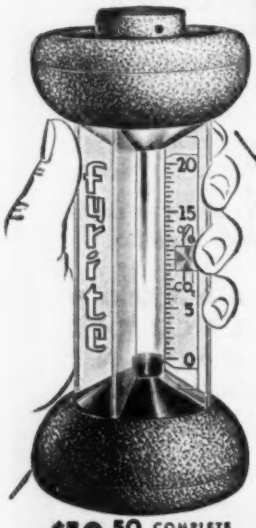
PRACTICAL CO_2 INDICATOR

MAKES ACCURATE
FLUE GAS TESTS
EASY



$18.50 COMPLETE WITH INDUSTRIAL TYPE FLUE FILTER

CO_2 analysis of the flue gases is the only method available for determining the percentage of fuel wasted up the stack. The convenient FYRITE CO_2 Indicator makes accurate flue gas tests easy—quickly pointing the way to adjustments and repairs necessary to secure efficient fuel utilization. The FYRITE requires no skill or technical knowledge; is simple and rugged; has no valves, clamps, or leveling bottle; no glass parts or batteries. It is widely used as a practical aid to save fuel, stretch steaming capacity, and reduce furnace maintenance.

For particulars about the FYRITE CO_2 Indicator write for Bulletin 341.

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OXYGEN INDICATOR
designed on same principle
available soon.
Ask for Information.

Frictional Phenomena

Concluded from page 393

upper surface of the steel strip has been carefully ground and polished to duplicate or approximate the surface a good bearing would have.

About 2 inches above the steel surface is a light board about 4 inches wide and hinged on its side so that it can either cover or uncover the surface of steel. Down the underside of this light board and over the middle of the steel plate a copper wire is imbedded in the full length of the board.

At T is an electric timer, a synchronous electric motor which operates a spark coil so as to give 30 sparks per second. the copper wire in the cover board is attached to one terminal of the sparking device and the other terminal to the steel plate. At F are shown blocks of different kinds of metals which have a short pointed mast sticking up out of the middle of the block. One at a time, these blocks are placed at the upper end of the steel plane and held by a spring grip G.

On starting the timer electric sparks pass from the point of the mast to the wire in the cover board and in doing so puncture a thin narrow strip of paper spread over the underside of the cover board. When the block is released and begins to slide down the plane, sparks jump from the mast to the wire and puncture the paper with a series of tiny pinholes. Inasmuch as the block is being accelerated in its motion, the distances between successive punctures grow larger and larger.

The metal block slides down the steel plate and if the metal is Babbitt metal, then on the strip of paper is a record for the acceleration (a) to be had for two surfaces,—Babbitt metal and steel. By means of the protractor and plumb-bob arrangement P, the angle θ is measured.

Knowing (a) and θ we may now calculate what μ is for these two surfaces.

To measure (a), the distances between successive punctures are first measured. A vernier caliper is useful for small distances, while for the larger ones a ruler may be used.

Recalling that our unit of time is 1/30 of a second, we shall use it as a unit and we can show that $d_2 - d_1 = d_3 - d_2 = d_4 - d_3 = etc. = a_1$ because these differences are also equal to the differences in velocity at the ends of the corresponding intervals of time i.e., $d_3 - d_2 = v_2 - v_1$, $d_4 - d_3 = v_3 - v_2$ etc., but by definition $v_2 - v_1 = v_3 - v_2 = a_1$ which is the acceleration for our specific unit of time, viz. 1/30 of a second. If a_1 is the acceleration for 1/30 of a second, (a) which we wish to use in the equation for μ will be the acceleration per second.

$$a = 900a_1$$

Knowing (a) and (b) we can substitute in $\mu = \tan \theta - a/g \cos \theta$ and find the value of μ.

This has been found to be a very satisfactory method.

Coulomb in 1781 made an extensive study of friction and enunciated certain "laws" which were afterwards confirmed by Morin (1830-1834). These laws have been found to hold within fairly wide limits.

1. Friction is proportional to the normal pressure between the surfaces of contact, and therefore independent of the areas of the surfaces.

2. Friction is independent of the speed with which the surfaces slide one on the other.

Coulomb stated long ago that a distinction should be made between static and dynamic friction. In Fig. 1 the pull on the dynamometer is greater at starting than when the block is moving steadily forward. In the repose method, Fig. 2, the angle θ has to be made larger for starting than the θ which keeps the block moving uniformly down the inclined plane.

At rest the block appears to have settled its hills into the valleys of the other surface and therefore it is harder to get started. This means a greater coefficient of friction in starting than in moving steadily.

Reduction in friction of bearings by lubrication has al-

The Key to Victory

Instrument control of temperature or pH in industrial processing is less spectacular than the location of enemy submarines or airplanes by the same method, but it is just as important, for it makes uniform mass production possible.

Potentiometers are synonymous with processing accuracy and for more than a quarter century most of these instruments have depended on Eplab Standard Cells for reliable performance. These cells are a "yardstick" for the translation of voltage to temperature or pH. The first commercial cells of their type made in America, they have become "as standard as sterling" through untiring research.

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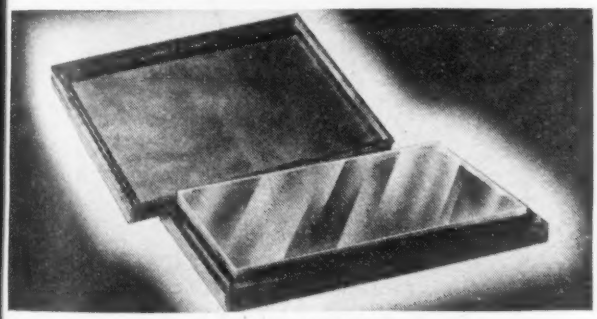

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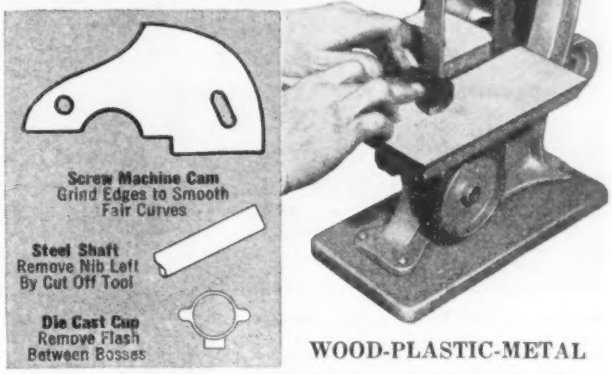
with the

Mead Industrial Burring Machine


Screw Machine Cam
Grind Edges to Smooth Fair Curves
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New circular explains, illustrates 18 ways in which the Mead Industrial Burring Machine saves time and money—also contains special Grit Guide. Every industrial plant needs this "Jack-Of-All-Trades" machine. Your burring can be done in "free time"—install these machines by every machine tool which leaves burrs. Grinds, finishes both outside and inside cut-out openings. Immediate delivery in most cases. Write for the informative Money-Saving circular now.

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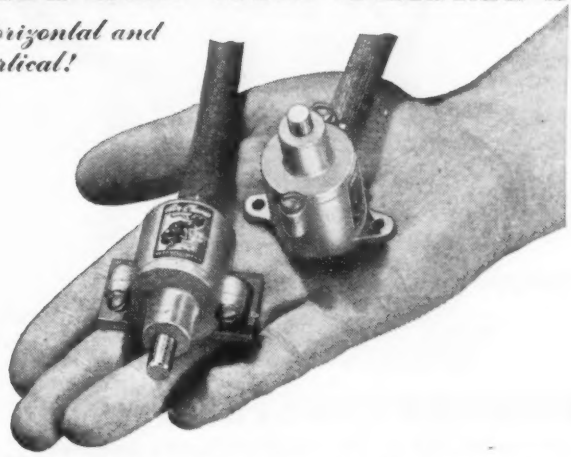
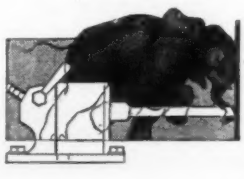
Horizontal and Vertical!



Both models deliver 80 lbs. pressure on a line pressure of 100 lbs. They'll save countless man-hours in assembly operations involving welding, riveting, bolting, etc. *Advantages over mechanical clamps:* 1. Any number can be operated by single master valve. 2. Easily installed in cramped corners. 3. Equal ram pressure at any stroke point. Send for new Mead AIR POWER Catalog, describing our line of Air Clamps, Air Vises, Air Presses, Work Feeders, Valves, Controls, etc.



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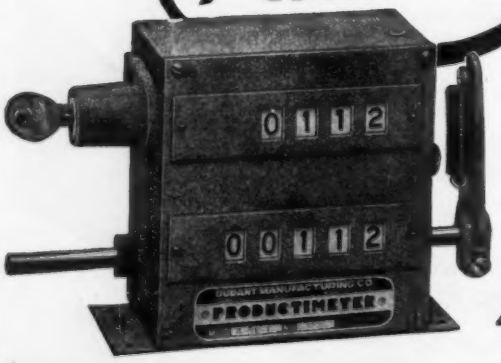

Model 4-5-E-1

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give accurate, "on the dot" records of machine production . . . help maintain exact schedules . . . provide a check on operating efficiency. There's a unit for practically every need. Model illustrated is two counters in one: top row records current run; bottom row is totalizer . . . designed for keeping separate records of production and daily or weekly totals. Exceptionally strong, durable . . . made with customary Productimeter precision.

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DURANT MANUFACTURING COMPANY

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ready been mentioned. The greatest reduction has been accomplished by rolling friction. In Fig. 6 is shown a beautiful model, of French construction, for reducing friction. A light aluminum wheel on a carefully ground steel axle is

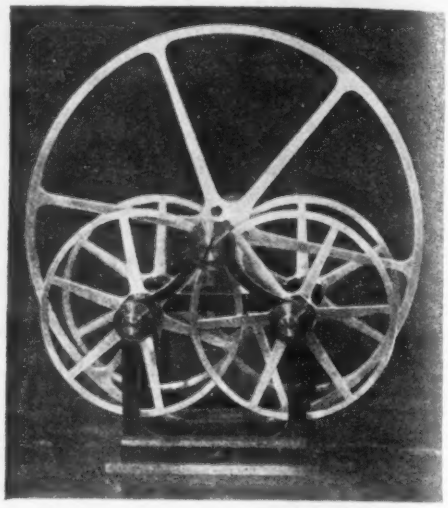

Fig. 6. The axle of the large wheel rests in the intersections of the smaller wheels. The friction of this bearing is small.

supported by four other light aluminum wheels whose axles are mounted in a cone bearing. This is the type of bearing one often sees on large grindstones. Fig. 7 shows a modern ball bearing. Both ball and roller bearings are used extensively in our modern conveyances and by their use friction has been tremendously reduced. To show that rolling friction is much less than sliding friction, the block in Fig. 1 is placed on a crude wooden cart in Fig. 8. Although the

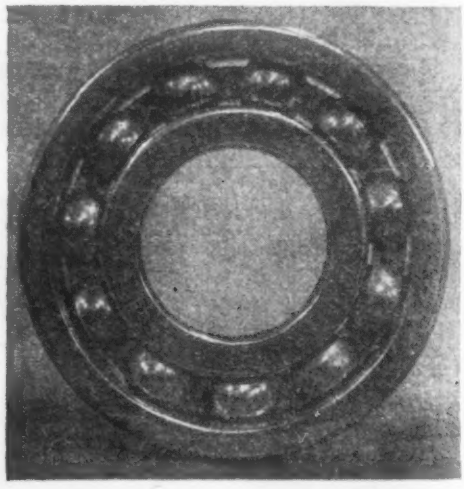

Fig. 7. A modern steel ball bearing.

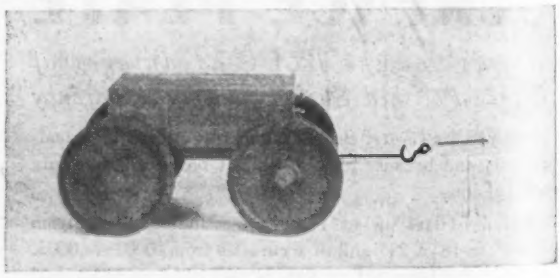

Fig. 8. The wheel reduces friction.

cart weighs almost as much as the block the horizontal pull to keep the cart and block going steadily along is less than 1/20 of the pull when the block is sliding along the same surface.

The wheel was one of the greatest inventions of all time.

THE MODEL 710

VOLT-OHM-MILLIAMMETER

Sensitivity —
1,000 OHMS PER VOLT
ON BOTH A.C. AND D.C.!!

Measures:—
A.C. AND D.C. VOLTAGES UP TO —
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A.C. CURRENT UP TO —
3 AMPERES
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30 AMPERES
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10 MEGOHMS

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Specifications:—

6 D.C. VOLTAGE RANGES (1000 OHMS PER VOLT)
0 TO 15/60/150/300/600/1500 VOLTS.

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A.C. CURRENT RANGE:
0 TO 3 AMPERES.

5 RESISTANCE RANGES:
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Model 710 uses a 4½" square 0 to 400 Microampere meter. All calibrations printed directly on meter scale in large easy-to-read type. Instrument is housed in rugged, heavy-duty Oak cabinet. Operates on self-contained batteries—no external source of current required. Comes complete with self-contained batteries, test leads and instructions. Size 6" x 10" x 10".

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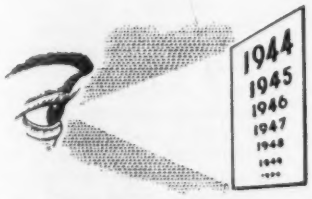

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Illustrated data sent on request.
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BRADLEY LABORATORIES, INC.
82 Meadow Street, New Haven 10, Conn

Power House Instrumentation

Continued from page 404

hand methods impossible. For coal handling in some of the small plants, and even in medium-size plants, the use of the monorail system can prove of great advantage. This can be expanded to use an electric hoist for raising the load, which may be hand-loaded, and again raised to the stoker hoppers. Scales can be interposed in the line of travel for recording the consumption; and with the boiler flowmeters evaporation can be determined. The lateral movement of the monorail can be either by motor or by hand.

We have applied this system successfully in under-flow ashpits where the bucket is designed to collect the ashes direct from the ash hopper by having it left in place until ready to raise, with no manual handling of the ashes.

A properly-designed instrument board for each boiler, or often combined with one board centrally located for two or more boilers, usually carries the following instruments:

Steam flow, sometimes carrying air flow or CO_2 indicating and recording instruments. These may be combined to indicate flue temperature, steam pressure, and indicating drafts, to suit the method of firing, at times carrying as many as ten pointers on the larger units for draft readings.

Combustion control instruments with manual cut-in switches are often mounted on the instrument panel, thus placing control of the whole operation at one point. Even large units can be successfully operated by a single man.

Automatic coal scales above the stoker and under the overhead coal bins feed and automatically weigh the coal to the stokers. Wide stokers, especially of the chain grate type, can be equipped with chutes designed not only to distribute coal over the whole width, but also distribute the sizes in the coal to give a uniform mixture and prevent uneven fuel bed conditions.

With the advent of the spreader stoker, now quite popular, the necessity for some of these features of operation as mentioned can be dispensed with, since the spreader stokers give uniform distribution on the grates. In this type of equipment, fly ash collection is automatically returned to the furnace by air jets, which saves considerable labor of handling. These stokers are now equipped for automatic discharge of ash by means of traveling grates, thus eliminating the time and labor required to dump the grates, which also reflects on continuity of efficiency.

Judicious water-cooling of furnaces, which are being adapted to already-installed boiler units, reduces manhours and maintenance of brickwork and furnaces; eliminates slicing of side walls at the fuel bed level; and increases boiler capacity.

A recent example of such a problem is an installation of three 350-hp. boilers, equipped with forced-blast chain-grate stokers, where a simple addition

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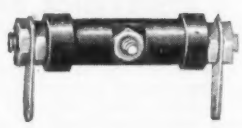

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Special terminals, or pre-soldered lead wires, prevent overheating during assembly. Standard units sealed with waterproof lacquer, critical-application units potted in wax. Standard "pellets" gold coated on front surface, forming positive contact, for critical applications, gold used on both sides. High leakage, but very low forward resistance. Highly adaptable mountings.
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Ask for samples and full technical data.

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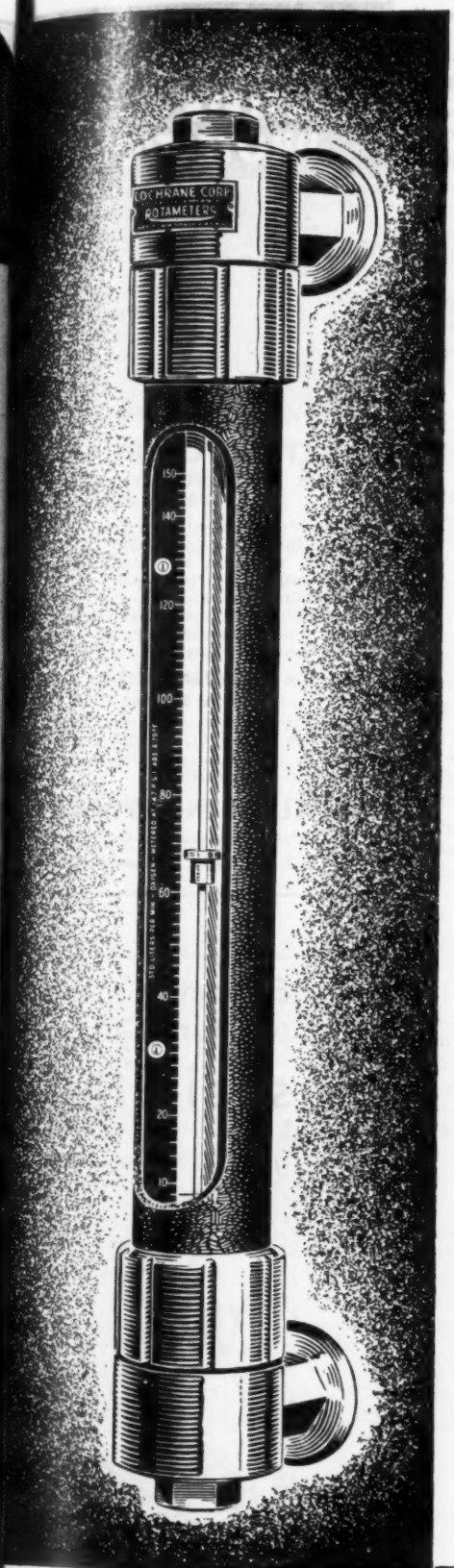

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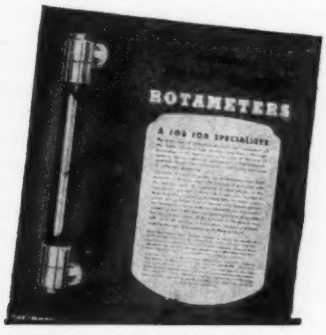
4. EASY ADJUSTMENT OF STUFFING BOXES **by Turning Milled Nuts with a Spanner Wrench** in one operation compared with other types, where it is neccessary to take up successively 4 bolts or screws.

5. EASY TO READ. **White-backed Metering Tube** permits quick and accurate reading of float position even under poor lighting conditions. An integral part of the tube, it cannot get dirty.

6. EASY TO CHANGE FROM ONE SERVICE TO ANOTHER. **Removable Calibration Scale** permits changing from one service to another. New scales can be furnished quickly without recalibration, or purchase of new tube or float.



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Cochrane, in announcing this line of Rotameters, finds itself fortunate in its association with a group of specialists with years of experience in the highly specialized field of glass fabrication and the technique of calibration procedure. In this organization will be found some of the men who helped pioneer the development of the American rotameter into a successful measuring device with interchangeable precision-bore tubes. The engineering phases of the work are in the care of men with years of training in the calculation, design, calibration and application of these products.

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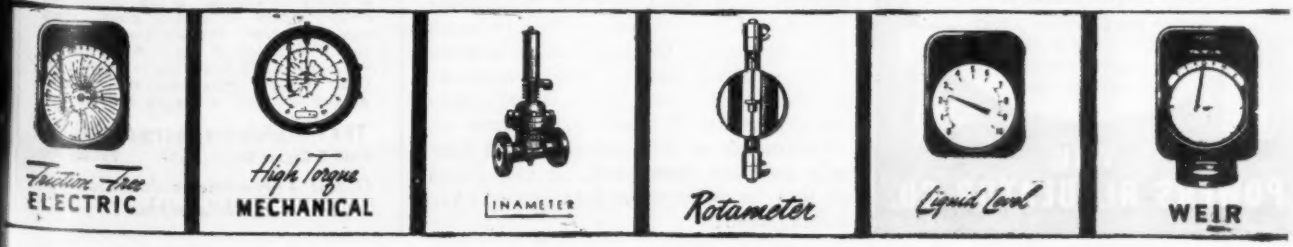

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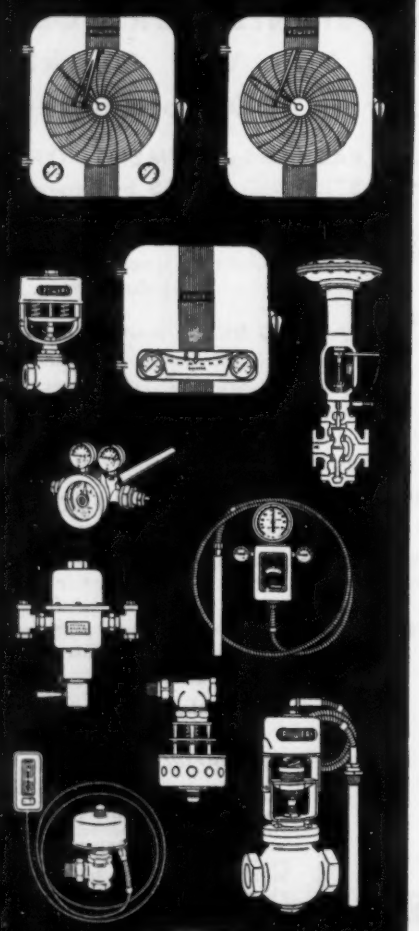

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of side water-walls and side water-wall headers, and a better means of ash disposal from the rear of the boiler instead of raking to the front, enabled this plant in the present heating season to carry a 100 percent additional heating load, with no additional labor.

Automatic over-fire air application was employed and the combustion arches eliminated; and there have been none of the interruptions for brickwork repair which were usual with the former operation at half the load now carried. Also, no slicing of side walls is necessary, as was necessary in the case of the former operation at the former load.

Another useful instrument which can be applied to the industrial plant is a meter to measure makeup water to the boiler plant. This at once shows the losses that occur in comparison to the steam generated, and is usually read in percent. This may represent avoidable or unavoidable losses; in any event it is one of the most definite ways to determine the losses—and few industrial plants know what their makeup percentage is. It will also reveal how well the heating load is balanced with the electric load. In one large plant a flowmeter was installed on the atmospheric relief valve, where all excess steam escaped to the air. To start with, this represented a large percentage of the steam generated; but by its use, and balancing electric and steam-driven equipment, this loss was reduced to a minimum, saving man-hours in coal- and ash-handling, and enabling the plant to operate on one less boiler.

A recent survey by this method revealed that the plant makeup was 50 percent. Investigation showed that live steam was used in many places where exhaust steam would do the same work, and where hot water with storage facilities would cut down peak demands on the boiler plant. This, with other economies, was sufficient to enable them to dispense with a fireman helper.

A common loss in the heating system of many plants is the flagrant use of cold water in the ordinary steam-operating vacuum pump to reduce leaking steam. This often causes overflowing feedwater heaters and loss of condensate to the sewer.

We also find that few plants are provided with surge tank capacity to take up the slack between boiler demand and condensation return slugs from the heating system. As these do not occur together, the result is loss of pure condensate, increasing makeup and requiring additional chemical and boiler washing and cleaning.

Thus it will be seen that there are unlimited opportunities for instrumentation which would contribute to manhour savings if the application is carefully studied and skillfully applied; and in most cases these installations soon pay for themselves. Returns on investments of this nature should usually pay for themselves in two years or less, in order to be attractive to the management.

A STRONGER FACTOR
in TODAY'S NEW
COMPLETE CIRCUIT
PROTECTION

EXTRACTOR POSTS
WITH ELECTRICALLY WELDED SIDE TERMINALS

Terminals integral with inner shell mean more strength against extreme shock, vibration and temperatures. Maximum electrical conductivity. New construction for convenience and durability. Shock-proof visual inspection. Specially designed grip prevents fuse from dropping out.

Send for B/P and ENGINEERING DATA
Ask for Samples

342001 finger-operated for 3 A G fuses illustrated. Also furnished screwdriver operated meeting Underwriters' specifications.

LITTELFUSE INCORPORATED
4757 Ravenswood Ave., Chicago 40, Ill.
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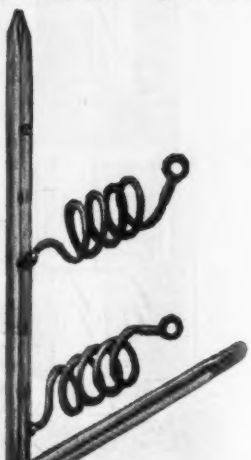
For Extremely Close
Temperature Control
Visual-Stats



● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

The Philadelphia Thermometer Co.
Sixth & Cayuga Sts. Philadelphia
Oldest Thermometer Manufacturer in Philadelphia

LOOK OVER THE FIELD

(when you buy Industrial Thermometers)

You will find some very excellent instruments available. Check them carefully; compare their relative merits. Then—if you find the *quality, accuracy,* and the ability to "take it" of Precision Thermometers as outstanding as we think you will—we'll be looking for your order.

Write for Bulletin "E", our new catalog of "Engineers' Type" and other Industrial Thermometers.

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ADVANCED ENGINEERING

demonstrated by

THORDARSON

COMPACT, HERMETICALLY-SEALED TRANSFORMER FOR AIRBORNE SERVICE

A type of hermetic seal construction to meet the newest rigid requirements of the Armed Forces.
High efficiency in a small package . . . this compact high frequency power transformer (60 to 2600 c.p.s.) fills a difficult airborne application.
Since the terminal seal employs metal and glass, absolute protection is assured against all performance difficulties usually caused by climatic changes.

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THORDARSON ELECTRIC MFG. CO.
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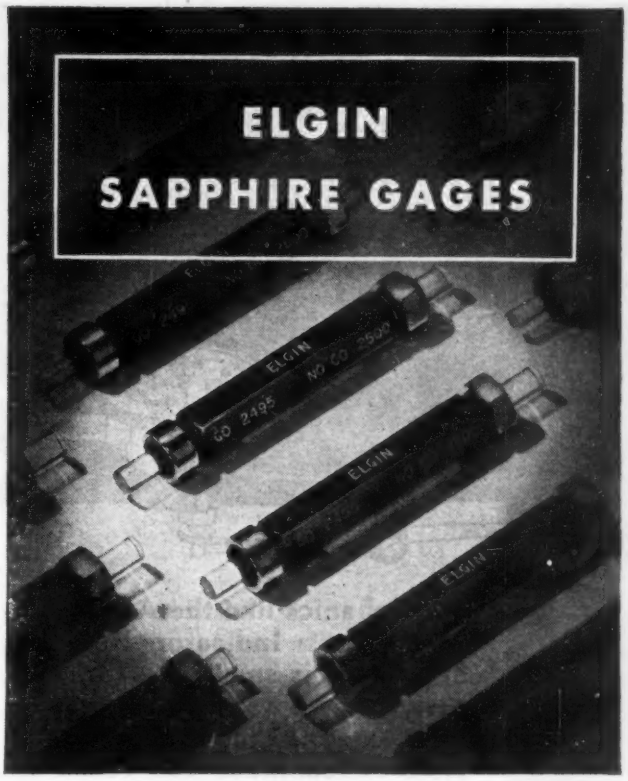
Transformer Specialists Since 1895
ORIGINATORS OF TRU-FIDELITY AMPLIFIERS



After 60,000 gagings

not even five millionths of an inch wear!

ANOTHER *factual* report of their amazing performance: Elgin Sapphire Plug Gages have delivered 60,000 gagings for the American Perforator Company and still do not show even five millionths of an inch wear. And yet those gagings were made on holes charged with a residue of grinding compound!

American Perforator compared the wearing qualities of Sapphire Gages with that of other types. On comparable gagings, tungsten carbide plugs wore out after a maximum of 23 days, hard steel plugs wore beyond use within 1 day . . . while Elgin Sapphire Gages were still on the job after 60 days with less than five millionths of an inch wear.

There's *no wear allowance necessary* with Elgin Sapphire Gages. They can't rust, burr, corrode or become distorted with use. Write for prices and complete information about beautiful, *durable* Elgin Sapphire Gages. Sizes from .040″ to .250″ and with tolerances as fine as .00002″.

ELGIN SAPPHIRE PRODUCTS PRESENT MANY ADVANTAGES
for the following types of equipment: Ring Gages • Bearings Thread Guides • Extrusion Dies • Gages • Knife Edges • Spray Nozzles • Sapphire Lapping Powders • Diesel Injector Nozzles • Oil Burner Nozzles • Soft Wire Dies • Phonograph Needles • Cutting Tools for soft metals • Burnishing Tools for soft metals • Pressure Vessel Windows • Electrical Insulators • Watch Crystals • Honing Stones.

America's best equipped sapphire fabricator

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AMES No. 22A UNIVERSAL DIAL TEST INDICATOR

Mechanics like the AMES Universal Test Indicator No. 22A because it is small and compact, easy to set up and adjust, can be used on numerous testing jobs, and with Hole Attachment can reach internal surfaces and places that are hard to get at. Packed in deluxe wooden box.

B. C. AMES CO.
WALTHAM, MASS., U.S.A.

INSTRUMENT SOCIETIES CALENDAR

City, Society and Secretary			Date	Place
Atlanta	Georgia Society for Measurement & Control	Roger W. Allen, 376 Nelson St., S.W., Atlanta		
Baltimore	Baltimore Industrial Instrumentation Society	C. B. Willnecker, 6732 Danville Ave., Dundalk, Md.		
Chicago	Chicago Society for Measurement & Control	A. J. Butler, 2626 W. 31st Blvd., Chicago		
Cleveland	Cleveland Instrumentation Society	F. G. Meulenberg, DuPont Experimental Lab.		
Gulf Coast	Gulf Coast Instrument Maintenance Men's Ass'n	T. H. Pierson, 3030 Roberts St., Beaumont, Tex.		
Hartford	Hartford Society for Measurement & Control	Stephen J. Zelle, Whitney Chain & Mfg. Co., Hartford, Conn.		
Kansas City	KC Industrial Instrumentation Society	Gordon H. Burke, Burke Engineering Co.		
Newark	New Jersey Society for Measurement & Control	Robert H. Gray, 84 Centennial Ave., Cranford, N. J.		
New York	New York Society for Measurement & Control	H. R. Kalbfleisch, 144-35 No. Blvd., Flushing, N. Y.		
N. Indiana	Northern Indiana Soc. Measurement & Control	R. W. Schreiner, 4 Waltham St. Calumet City, Illinois		
Philadelphia	Philadelphia Society for Instrumentation	J. E. Gambrill, 1317 Spruce St.	Sept. 20(B)	Engineers Club
			Sept. 25(B)	Roosevelt Hotel
			Oct. 23(B)	Roosevelt Hotel
			Nov. 27(B)	Roosevelt Hotel
			Dec. 18(B)	Roosevelt Hotel
Pittsburgh	American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pgh.		
St. Louis	St. Louis Society for Instrumentation	Gus Holubeck, Union Electric Co., Venice, Ill.		
Toronto	Canadian Society for Measurement & Control	T. C. Agnew, Minneapolis-Honeywell Reg. Co., Toronto		
Washington	Instruments Society of Washington	W. A. Wildhack, 328 N. Oxford St., Arlington, Va.		

Let's Have News Anyway!

In spite of no meetings in summer, keep your Society in print! Secretaries (and others) please send me items—even "personals"—to run on this page. I can't make up news items out of my head: I've got to RECEIVE them! The reason why there's only the calendar this month is that I received nothing—not even a hastily-written postal card giving a brief news item. Even my own friends who belong to societies, in their recent letters on various subjects, forgot to include news of their societies. I know that all members of all societies are justly proud of their work, so *why not tell the world?*

—M. F. BEHAR, *Editor*

NEW POST-WAR PRODUCTS AVAILABLE FOR MANUFACTURE AND DISTRIBUTION UNDER LICENSE

•

ELECTRIC MICROMETERS
ELECTRIC THERMOMETERS
ELECTRIC TACHOMETERS
ELECTRIC HYGROMETERS

Remote Electrically Indicating, Recording and Controlling.

Operate from commercial voltages and frequencies through a new system of Micro Electrical Measurement.

Providing simple accurate and permanently dependable performance.

We develop Electrical Instruments for manufacture and distribution under license.

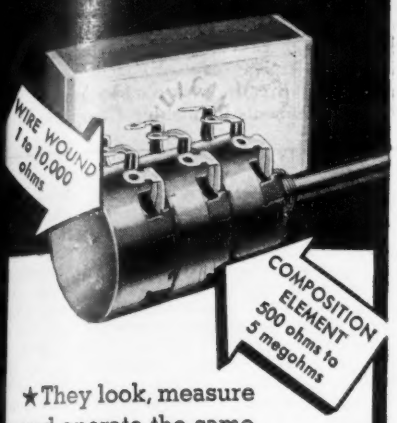
•

Correspondence Invited from Manufacturers Interested in Post-war Manufacture and Distribution.

•

ASHCRAFT AUTOMATIC CONTROL COMPANY
1415 WEST HOWARD STREET
CHICAGO, ILLINOIS

Matched
MIDGET CONTROLS



★They look, measure and operate the same —these Clarostat wire-wound and composition-element midget controls. Fully interchangeable, mechanically. Can be made up in various tandem assemblies.

Clarostat Type 37 midget *composition-element* controls have been available for several years past. Their *stabilized* element has established new standards for accurate resistance values, exceptional immunity to humidity and other climatic conditions, and long trouble-free service. 1 watt. 500 ohms to 5 megohms.

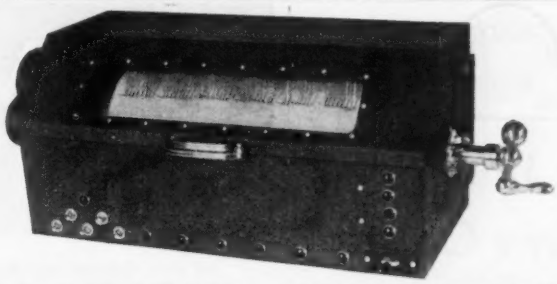
And now the Clarostat Type 43 midget *wire-wound* is also available, to match Type 37—matched in appearance, dimensions, rotation, switch. 2 watts. 1 to 10,000 ohms.

For neatness, compactness, convenience, trouble-free operation—just specify Clarostat *matched midget controls.*

★ *Write for literature . . .*

CLAROSTAT *Controls and Resistors*

CLAROSTAT MFG. CO., Inc. · 285-7 N. 6th St., Brooklyn, N. Y.



ELECTRIX REKORDER

The most versatile Chronograph. Invaluable for graphic recording in . . . production . . . control . . . biology . . . research . . . timing . . . and any qualitative phenomenon. Synchronous drive for "dead-beat" accuracy. Nine remarkable speeds. FOB factory, either type $245.00

DRUM TYPE. All-aluminum drum holds chart paper 25 cm by 50 cm. Supplied with up to 50 stylui to provide 50 simultaneous recordings. Drum turns one revolution (50 cm of chart) at any of the easily selected speeds of 1 min. . . . 5 min. . . . 15 min. . . . 1 hr. . . . 4 hrs. . . . 12 hrs. . . . 1 day . . . 1 week . . . 4 weeks. By use of low-cost screw-feed attachment a single continuous spiral recording up to 2,500 cm. long (80 ft.) may be had on single chart.

CONTINUOUS ROLL TYPE. Employs roll of recording paper from 5 to 25 cm. (2" to 10") wide in lengths up to 125 feet. Same nine speeds. By using widest paper and 50 styli, more than a mile of graphic can be done, unattended, on a single roll.

On either type of Rekorder, any conventional type of recording system can be used with proper instruments such as magnet energized pencil or inked pens or using pressure sensitive waxer paper. However, the Rekorders are supplied complete with styli for use with Electrix paper which instantly and permanently records when a small current passes thru the stylus onto the paper. Write for details about the Rekorders . . . about Electrix paper . . . about the MONODRUM chart mover with 22 speeds . . . and about the DUALDRUM chart mover with 36 speeds and overall speed ratio of from 1:1 to 1:10,000,000!

Correll & Correll
Chicago Heights, Illinois

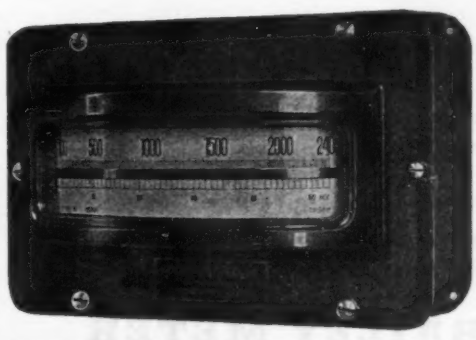
WHAT do you need in a PYROMETER ?

SENSITIVITY RESISTANCE DURABILITY SIMPLICITY

Engelhard Direct Deflection Indicators have all these features . . . Accurate sensitivity to the most minute voltage variations due to suspension type construction . . . High resistance per millivolt and no appreciable error when used with thermocouples of different resistances and on connecting leads of considerable length . . . Sturdy construction, adapted to use under severe conditions without danger . . . So simple that instant readings may be made directly in either millivolts or temperatures by someone unfamiliar with the principles of pyrometry . . . On kilns or furnace installations, where "spot readings" are desirable—the Engelhard Rotary Switch permits separate readings from many points.

Write for Catalog

PORTABLE MODEL P-1



WALL TYPE W-1

CHARLES ENGELHARD, INCORPORATED
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BAILEY METER CONTROL SYSTEM

The Mark of

Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

C-3

BAILEY METER COMPANY

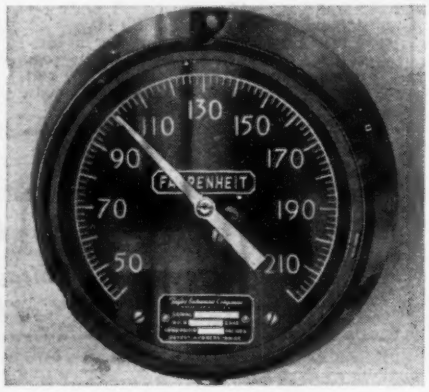
1041 Ivanhoe Rd., Cleveland, Ohio

The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department. Or write to Information Section, Instruments Publishing Company.

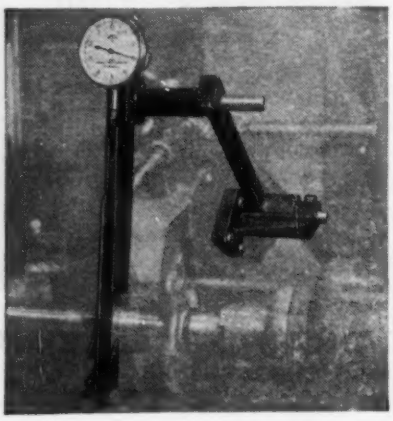
4½" Dial Thermometer with Plastic Case

New "53K Series" mercury-actuated 4½" Phenolic case dial thermometer, originally built for the shipbuilding industry, is built to withstand severe operating conditions. Available with "Accuratus" tubing, it is said to be especially well suited to installations requiring a long length of tubing between bulb and instrument. Plastic case is resistant to corrosion and shock. To facilitate reading at a distance, metal dial is finished in black with white figures. New instrument is available with a wide variety of standard bulbs and in the following Fahrenheit ranges: —40 to 120, 40 to 220, 350 to 550, 400 to 900, —10 to 110, 80 to 300, 300 to 750, 30 to 150, 50 to 400, 200 to 900.—*Taylor Instrument Companies, Rochester 1, N. Y.*



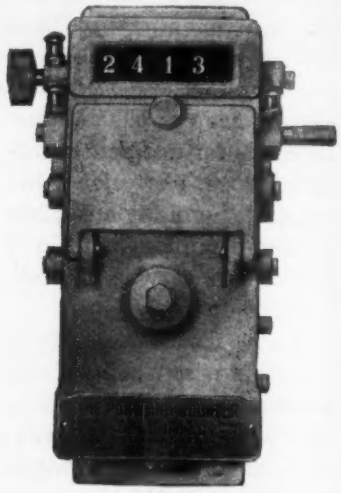
Indicating Gage for Work Being Ground

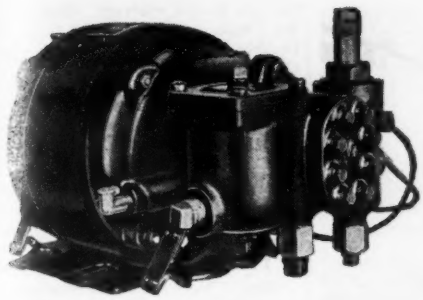
New "Stuart Micromatic Visual Grinding Gage" is for materially increasing the speed of precision grinding operations while maintaining the required degree of accuracy. It is applied to and taken off the work while the machine is in operation. Hand "miking" is eliminated. Dial indicator guides operator as work is ground to size. Gage indicates correct size even though the sizing controls of the machine may be worn. Grinding tolerances of ±0.0001" are said to be easily maintained. Operator fatigue is reduced, rejections minimized. Gage dial is actuated by "direct parallel thrust." Contact points of caliper measuring bar are of tungsten carbide for long wear. Gage is made in two models with ranges of ¼" to 1¼" and ⅝" to 2½" respectively. Additional calipers for the larger model provide ranges of 2" to 5" and 5" to 8".—*Clawson & Bals, Inc., 4701 West Lake St., Chicago, Illinois.*

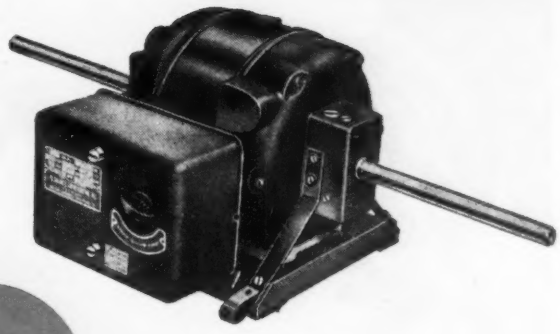


Predetermining Counter

New "Portland Anyset Control Counter" is a heavy-duty predetermining counter with an automatic repeat mechanism which can be set at any desired number and will automatically repeat in units of the set count without further attention. At completion of each set count a 110-volt switch is actuated to control operations. This control switch may be furnished for a manual reset (which requires depressing a push button at lower end of case); or an automatic type reset requiring counter to be operated through one count before being automatically reset; or in a 110-volt solenoid reset for remote control. Counter may be quickly and easily set to repeat at any number within its capacity, so that when desired quantity has been tallied, alarm signal contacts are closed during one count and control switch actuated. This switch may be furnished to make or to break contact at completion of each preset count and may be used to stop the machine or to start other operations. Mechanism is enclosed in a heavy dustproof case. Unusually large steel shafts in ample bearings with necessary hardened steel parts and extra-heavy construction, assure long life. It is adapted for speeds up to 400 counts per minute. Electric switch is rated at 110 volts 10 amps.; for higher capacities a starter switch or relay is necessary. Terminals are provided for alarm signals for either light or bell operat-





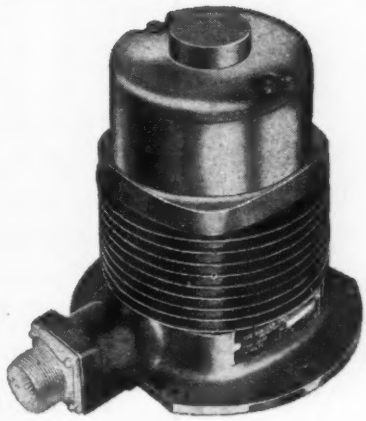


HOLTZER-CABOT

SPECIAL FRACTIONAL HP MOTORS DESIGNED TO FIT THE APPLICATION

If operating characteristics, speeds, hazards, ambients, etc., were always similar for products . . . standard "off-the-shelf" motors could be used for most cases. However, experience proves that operating conditions do vary in motor applications — and the only way to meet performance requirements is to use a special motor specifically designed to meet operating conditions such as load cycle, speed stability, speed control, reversal of rotation, atmospheric conditions, quietness, etc.

For over 50 years Holtzer-Cabot has concentrated its facilities in the design and application of special fractional HP motors to meet the exacting performance requirements of such products as instruments, aircraft, machine tools, business machines, etc. And although today all of our energies are being utilized in building motors for military products, our motor development engineers will gladly discuss your peace-product motor problems with you.



HOLTZER-CABOT

THE

HOLTZER-CABOT ELECTRIC COMPANY

Designers and Builders of Special Fractional HP Motors and Electrical Apparatus

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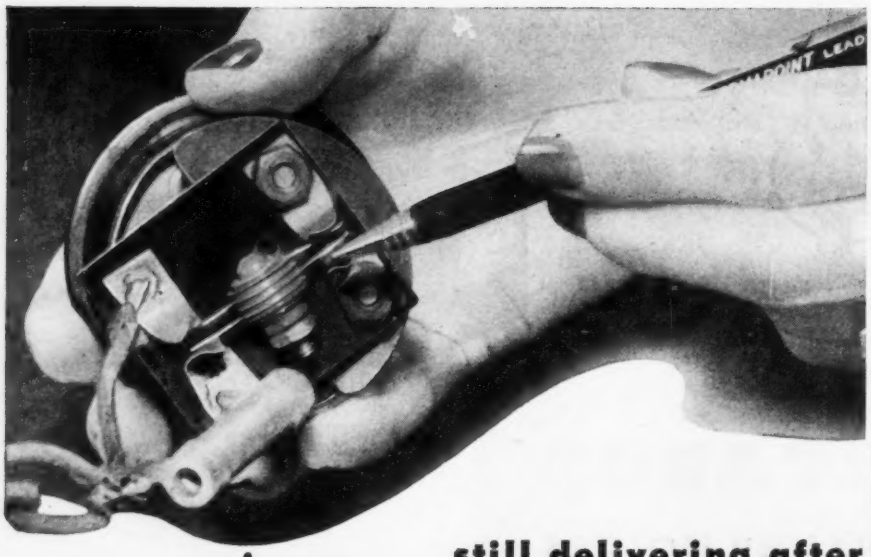


still delivering after

88,000 HOURS

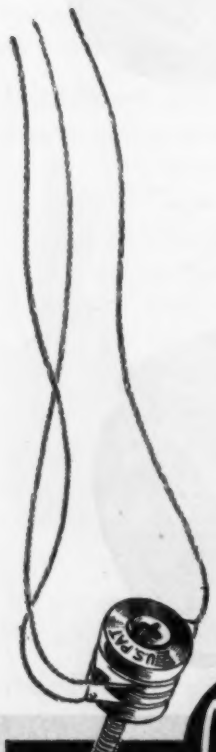
Continuous Service

This Conant type M rectifier was returned as defective on May 9, 1934. When routine tests failed to show any defects, this rectifier was mounted on the back of a 15 mil meter and put in operation as a line voltmeter, in an effort to detect any intermittent condition.

For more than ten years this "defective" Conant rectifier has been in *continuous service*—an estimated 88,000 hours—delivering a full 13 milliamperes, its original output. This is the milliampere-hour equivalent of several lifetimes of normal service.

This unintentional life test, begun a decade ago, makes it possible to safely predict a normal life of at least ten years for any Conant rectifier.

If it is important that your instruments retain their initial calibration *for life*—choose Conant rectifiers and be *certain*.



CONANT *Instrument Rectifiers*

ELECTRICAL LABORATORIES

6500 O STREET, LINCOLN 5, NEBRASKA, U. S. A.

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85 E. Gay St., Columbus, Ohio
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1215 Harmon Pl., Minneapolis 3, Minn.
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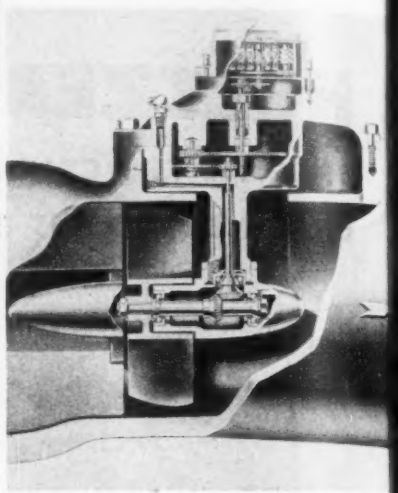
1526 Ivy St., Denver, Colo.
4214 Country Club Dr., Long Beach 7, Cal.
4205 N.E. 22nd Ave., Portland 11, Ore.
Caixa Postal 930, Sao Paulo, Brazil
50 Yormouth Rd., Toronto, Canada

ing on 6-volt current. Shipping weight, 1 lbs. Size of case, 10¾" × 4" × 3¾" Double contact switches are also available Controller is furnished for rotary move ments but can be adapted for reciprocating motion. One rotation of drive shaft counts one on either clockwise or counterclockwise rotation. Right-hand model has actuating shaft on right side (as illustrated); left hand counter has shaft on left.—*Adde Co., Portland 2, Maine.*

Propeller Type Liquid Meter

New "Model PRF Propeloflo Meter" is a propeller type meter for main lines (6" and larger). It is said to embody many improvements, including streamline Venturi



construction, 8-blade Bakelite propeller molded in one piece, and shafts rotating in ball bearings to assure maximum power to drive indicating and recording devices or proportioning chemical feeders. Venturi throat evenly distributes force of flow against full area of propeller, resulting in improved accuracy throughout "an exceptionally wide range of flow." Spiral flow is eliminated by straightening vanes just upstream of propeller. Propeller hub, bracket and nose are streamlined to reduce flow disturbance and divert fine grit, sand or scale away from mechanism. Unit is easy to service, it is said, owing to its "one-shot" lubrication system, readily accessible stuffing box, and the ease with which propeller mechanism may be removed for inspection. A blank cover may be installed when meter is removed.—*Builders-Providence, Inc., Codding St., Providence 1, R. I.*

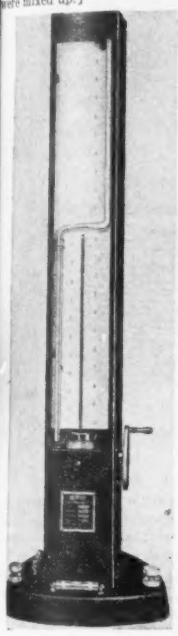
Direct-reading Megohmeter

New "TAC Model 400-H Megohmeter" is especially designed for checking capacitor dielectric, but is equally applicable to other high-resistance testing: 400 megohms to 100,000 meghoms. Resistance values are measured under an applied d-c. potential of 90 volts and are indicated on an individually calibrated scale. With an accuracy of 5%, instrument is stable enough to allow its use in production testing. A

built-in current limiter prevents damage to instrument if test terminals are accidentally shorted. Controls (master switch, range selector, and zero adjustor) are conveniently grouped on front panel, which also carries the resistance indicator, pilot lamp, and terminal strip. Latter is made of a non-hygroscopic high-resistance material so as to avoid error due to humidity. Measuring circuit, including 110-volt 60-cycle power supply and the test battery, is contained in a steel housing 8" × 10" × 8"; a hinged top panel gives access to interior for replacement of batteries or tubes.—*Technical Apparatus Co., 1171 Tremont St., Boston 20, Mass.*

Precision Manometer

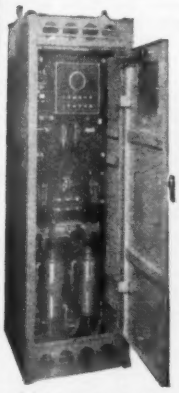
[Corrected item: as printed last month, several lines were mixed up.]

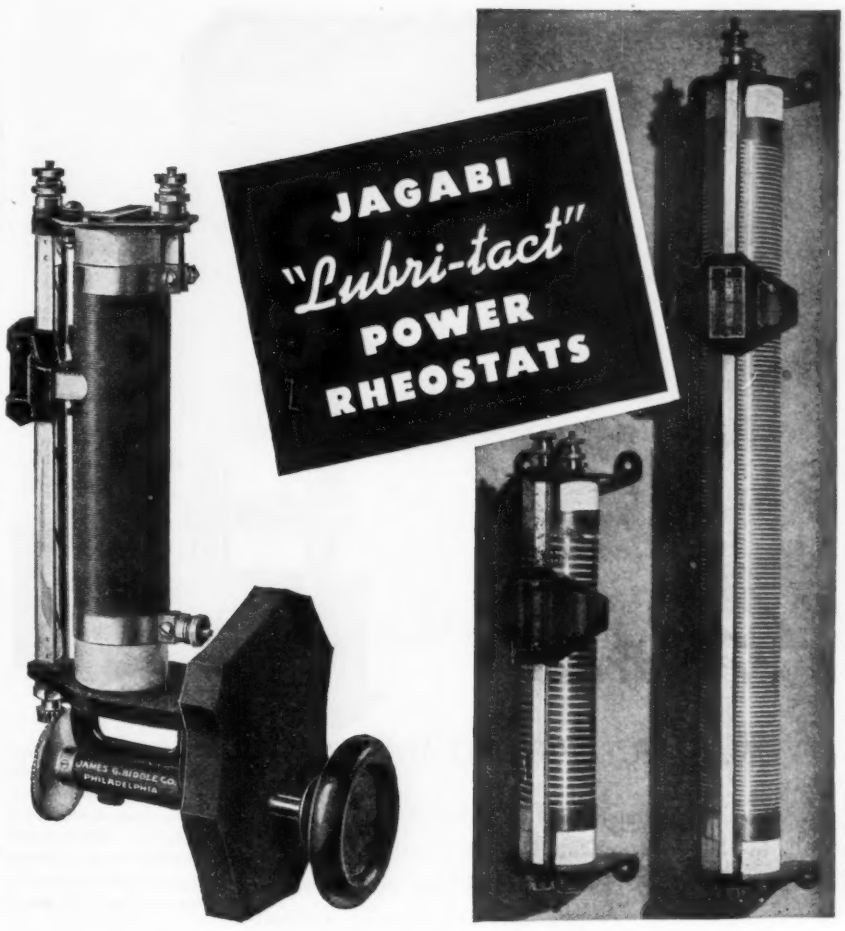


New "Meriam Micromanometer" has been developed for calibrating low pressure instruments and is suitable also for reading pressures and vacuums. A highly sensitive instrument, the Meriam Micromanometer permits readings to ± 0.001" water pressure. It is said to be "quite different from anything now on the market." In simplicity of operation it is said to surpass the hook gage. It is "not the least complicated or mysterious" and can be handled successfully by the average operator. — *The Meriam Instrument Co., 10958 Madison Ave., Cleveland 2, Ohio.*

Seam Welding Controller

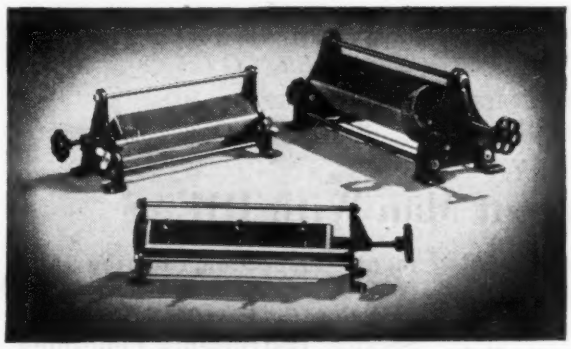
New "Type CR7503-B110" resistance welding control is designed exclusively for seam welding. It incorporates a completely electronic timing circuit and is especially suitable for operations where frequent changes of the timing pattern are required, such as when welding a variety of materials of various shapes and thicknesses. Operating on a 230/460/575-volt single-phase 60-cycle power supply, the control consists of a timing panel, a firing and a heat control panel, and a power panel, any one of which can be separately disconnected and removed to facilitate inspection or servicing. The electronic timing circuit provides accuracy of the timing pattern of the weld without utilizing moving parts and regardless of normal, instantaneous, or gradual line-voltage variation. Smooth heat control is provided by the phase-shift method. Complete control is mounted in a floor-type enclosure; full-length front and rear doors can be locked. A calibrated heat-control dial is located on a panel readily accessible through a flap opening in front door. Snap switches for providing independent adjustment of the "heat" and "cool" time in one-cycle steps from one to 30 cycles are also located on this panel. Thus the various settings can be seen at a glance. All tubes and connection terminals are conveniently located. Water supply inlet and





Whether for direct manual adjustment or for front-of-board control, Jagabi "Lubri-tact" Power Rheostats can be depended upon to do a real job where ruggedness, durability and maximum heat-dissipating qualities are required. Suitable for either d-c or a-c control in 4 sizes and 76 ratings from 30,000 ohms, 0.1 amp. to 1.6 ohms, 25 amps. Available in screw-driven fine adjustment types, and with metal cages, multiple sliders and other modifications.

Write for Bulletin 1745-I.



"JAGABI" COMPRESSION CARBON RHEOSTATS

Jagabi Compression Carbon Rheostats can be smoothly controlled by screw adjustment, and overloads of several hundred percent are permissible for short periods of time. Four sizes in current ratings from 6 to 65 amps. up to 55 to 800 amps.

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Write to Post-War Products Service, Instruments Publishing Company, Pittsburgh 12, Penna., giving a brief description of your idea, so that this Service may refer it to the interested companies.

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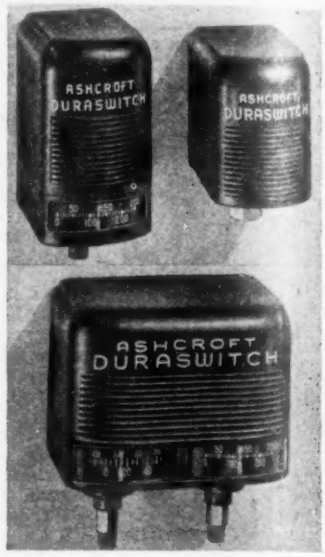
outlet fittings are on outside of enclosure. A row of indicating lights on front door show instantly whether (1) the water flow is adequate, (2) power has been applied and (3) the time-delay has timed out.—*Industrial Control Div., General Electric Co., Schenectady, N. Y.*

Temperature or Pressure Switch

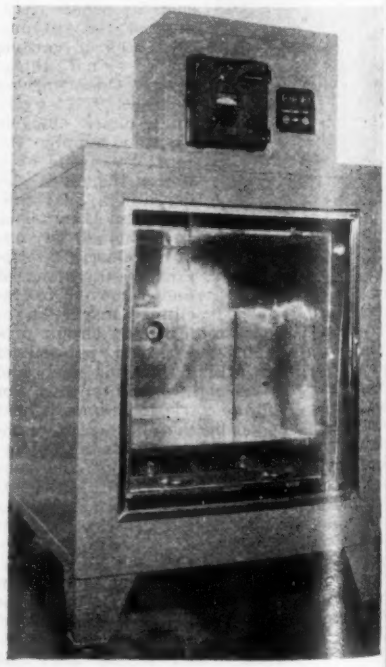
New Ashcroft Duraswitch" is a switch in combination with the Ashcroft Gage. A slide-rule type dial is easily readable for setting control point. "Series E-100" (above)



are for pressure only; "Series E-200" (below) are for both pressure and temperature applications, as a pressure control and pressure gage combination, or temperature control and thermometer combination, in single or duplex types.—*Electro Mechanical Division, Manning, Maxwell & Moore, Bridgeport, Conn.*

Constant-humidity Test Cell

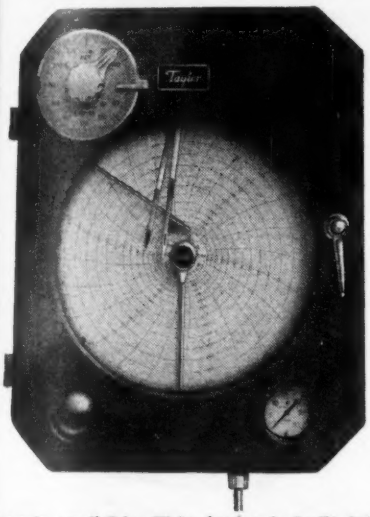
New "Model NL-B-4-15" and "Model NL-B-4-16" testing chambers were primarily designed for studying effects of microscopic layers of moisture (not to be confused with condensate) which form on most surfaces of radio and electronic equipment. Equipment consists of an outer chamber with



insulated walls and a stainless steel inner chamber. Electric heaters and blowers circulate air around outside of inner chamber; and self-balancing potentiometer type automatic temperature controller mounted at top controls this temperature to 0.25°C. Inner chamber has an independent circulating blower which passes the air over a stainless steel tray in which water, lead nitrate or other salt solution is placed. Air in inner chamber can be maintained at any point between 50° and 60°C., and the relative humidity after temperature stabilization will approach saturation and remain constant indefinitely. By varying the salt solution, several relative humidity percentages may be achieved and held to ±1%. Inside dimensions are 36″ × 30″ × 36″ for Model NL-B-4-15 and 24″ × 24″ × 24″ for Model NL-B-4-16. Either may also be equipped with a recording controller. — *Northern Laboratories Limited, 50 Church St., New York 7, N. Y.*

Process Timer

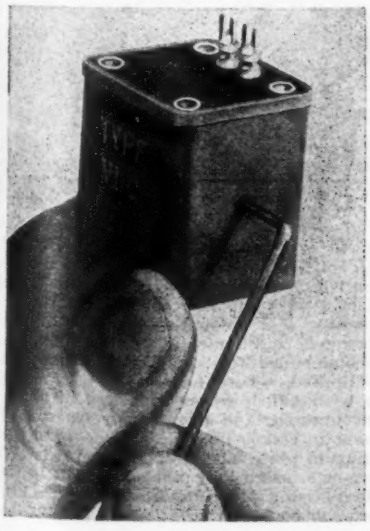
"Taylor Process Timing Mechanism for Fulscope Temperature or Pressure Controllers," production of which was suspended soon after the beginning of the War,



is again available. This device is built into maker's single-duty "Fulscope" temperature or pressure recorder-controller. For description see *Instruments*, Sept. 1940, page 273. —*Taylor Instrument Companies, Rochester 1, N. Y.*

Variable Inductors

New "UTC-VI-C" variable inductors are fully-tunable units, each with an adjustable range of 3-to-1, the obtainable inductance being from half to twice the mean value.



Where Listening calls for Courage

For Europe's enslaved millions, listening to radios today involves *danger*—and will so continue until after Victory, when free broadcasts can again be heard without fear.

Even in America, listening today involves *difficulty*—because, due to the priority of radio and electronic devices for military service, Americans are still using the same equipment that has served us since 1941.

And yet the amazing thing is how well—and how many—of America's 59 million radio receivers are still functioning . . . kept in operation by servicemen who are performing miracles to keep 'em listening. Their testimonials to Jackson's INTEGRITY OF DESIGN—that "hidden plus" of all Jackson Testing Instruments—are based on excellence of performance under most severe handicaps.

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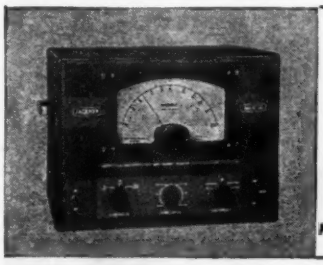

New Jackson Instruments, incorporating the advances of military experiences, will be available for the vast post-war radio market. Until then, maintaining Jackson products is a responsibility we shall fulfill as promptly as wartime conditions permit.

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Dials on STURTEVANT Wrenches do not have glass faces to glare, reflect, refract, crack, check, stain or break. The indicator pointer holds its fixed position—the clearly marked calibrations passing laterally below it. The tip of the indicator pointer just clears each raised or sharply depressed mark (you cannot cross-read below it). It is flared perpendicularly to screen out adjacent calibrations and prevent misreadings from side angles. Like the measuring element of STURTEVANT Wrenches, these improved dials are permanently accurate, they require no periodic re-settings.

BUY WAR BONDS

Write for Bulletin TW-13 Showing STURTEVANT Torque Wrenches in capacities from 0-40 inch ounces to 7200 inch pounds.

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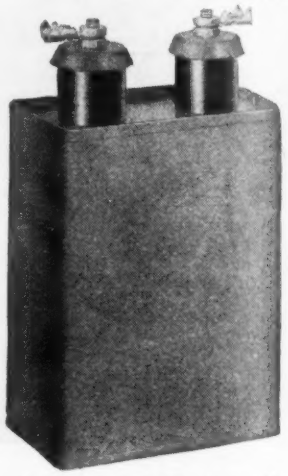
ADDISON QUALITY ILLINOIS

Nineteen standard types are available (on priority orders) with mean values from 8.5 millihenries to 33 henries. Announcement gives complete set of curves of important unit characteristics; also circuit diagrams and curves of circuit characteristics obtainable by combining new variable inductors with various other elements. Unit is housed in a die-cast case, weighs approx. 5 oz. Inductance is varied by means of an 8-32 set-screw (which may be turned by an Allen set-screw wrench) but screw can be replaced by a threaded rod to which a knob may be attached. New inductor is fruit of development begun in 1940 to find simple positive method of varying inductance of magnetic-core coil: the common permeability-tuned r-f. coil construction is not feasible at audio frequencies by reason of relatively small variation and relatively poor *Q*. New inductor has relatively flat *Q* in a-f. range.—*United Transformer Co., 150 Varick St., New York 13, N. Y.*

Rectangular Hermetically-sealed Capacitors

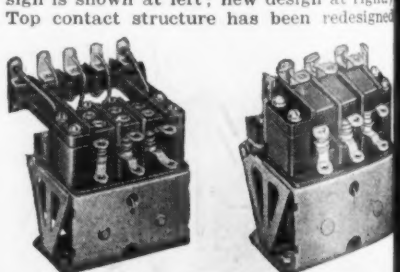
New line of rectangular oil-type capacitors is said to be complete. Made in standard container sizes and in voltage ratings up to 6000 v.d.c.w., these new "Capacitrons"



will meet Army and Navy specifications including total salt-water submersion tests. Capacitances of available units range from 0.1 to 10 mmfd. Prompt delivery is offered. —*The Capacitron Co., 318 W. Schiller St., Chicago 10, Illinois.*

Sensitive Multi-pole D-c. Relays

New "Type 27" sensitive multi-pole relays embody an improved design. (Old design is shown at left; new design at right.) Top contact structure has been redesigned

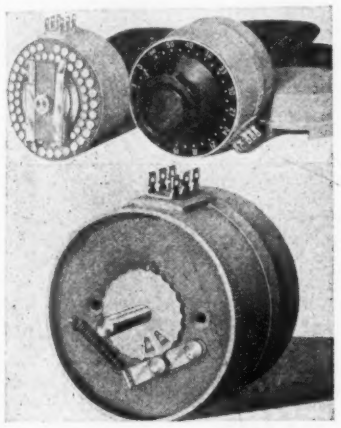


on the 3-, 4- and 5-pole relays. Formerly, all coil and blade contact terminals were located on an overhanging Bakelite bracket. Relays with the new top contact structure require less mounting space and are stronger mechanically. New relays are recommended for applications where space is limited, where heavy contact loads are to be handled, where vibration or shock is encountered, and particularly where power input to coil is limited, such as when operating in plate circuit of electron tubes. The two-coil design contributes toward efficiency. Magnetizing force losses at armature hinge, two-coil construction allows a greater num-

ber of wire turns for a given resistance, resulting in a greater number of ampere turns. Rigid framework provides exceptional immunity to effects of high acceleration, severe vibration or shock. Semi-balanced armature provides greatest possible vibration resistance within limited space. Contacts operate with a wiping action. Contact gram pressures are adjusted without bending contact springs; armature is adjusted without bending, and restoring spring tension is adjusted by a lever arrangement instead of by stretching the spring. These last factors contribute toward stability over long periods of use. Depending upon available power and on coil and circuit characteristics, contact capacity ranges up to 10 ampere continuous at 30 volts d.c. on inductive (motor) circuits based on operation at 53,000 feet altitude. Coils are both varnish- and vacuum-wax-impregnated and all metal parts are either non-corroding or are heavily plated. Will withstand severe humidity tests as well as the Army-Navy 200-hour salt-spray test (Spec. AN-QQ-91). Ambient temperature range —40° to 90° C. Weight 4½ to 6½ ounces, depending upon number of poles.—*G-M Laboratories Inc., 4300 North Knox Ave., Chicago 41, Illinois.*

Attenuators with New Detent Gear

New improved line of attenuators features a new detent gear, new materials and new type steel cover. New detent gear is said to provide more positive action, greater degree of accuracy, more uniformity in operation, longer life and a stronger stop mechanism. Contacts and switches are made of tarnish-proof silver alloy. Cleaning and lubricating of contact points are completely eliminated. New type steel cover provides improved magnetic shielding; body of cover forms part of attenuator assembly, protecting the resistors. A snap-on cap gives ready access to switch blades and contacts.—*The Daven Company, 191 Central Ave., Newark 4, N. J.*



Resistors for High-voltage Discharge Circuits

New "Meg-O-Max" resistors utilize an absolute minimum of critical materials, are capable of operating at high voltages and ambient temperatures, and also capable of dissipating power. They are claimed to present a degree of resistance stability and mechanical ruggedness unavailable in any other type exclusive of costly and hard-to-get wire-wound instrument multipliers such as maker's "Koolohm Meter Multipliers." Actually, "Meg-O-Max" is said to be superior to wire-wound types where broad tolerances are permissible: can be made in much higher resistance values for a given physical size, and can handle even higher voltages. "Meg-O-Max" resistors are formed of a series of pressed and sintered ring-shaped segments electrically joined in such a way as to cause units to be non-inductive. Finished units are encased in harmetically-

This man at the bench is not a Hero with medals, and no glory awaits him when his job is done. Unseen and unsung, he is on the job every day, working with hot glass, behind a fierce flame, with delicate fingers and skill, building one of the finest thermometers for his country's needs.

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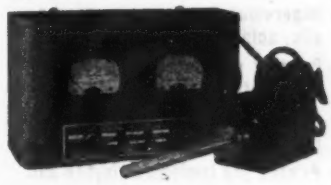

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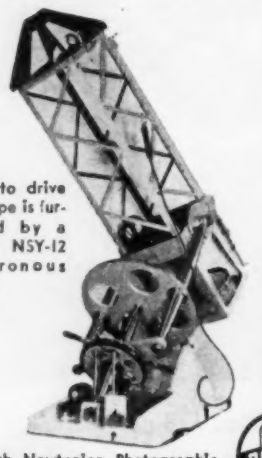

Power to drive telescope is furnished by a Bodine NSY-12 Synchronous Motor.

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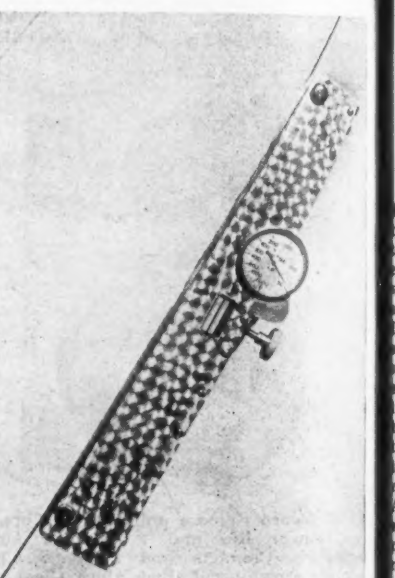
sealed glass envelope with ferrule terminals, capable of withstanding aircraft vibration tests, salt-water immersion tests and mechanical shocks produced by rapid acceleration. These new resistors will be suitable for use as high-voltage bleeders, coarse-accuracy multipliers for voltage indicators, various uses in high-voltage networks, measuring equipment, rectifier systems, high-voltage voltage dividers, etc. They are available in two lengths: "Type 1" 5 3/32" long, range from 3600 ohms to 100 megohms; "Type 2" 9 1/2" long, range from 6800 ohms to 100 megohms.—*Sprague Specialties Co., Resistor Div., North Adams, Mass.*

Cable Tension Meter

Newly-refined cable tension meter was originally developed during World War I, is said to be playing an important part in the erection and maintenance of lighter-than-air craft; and to have many other applications in aircraft and elsewhere. When it is desired to test the tension in rope or wire cables, instrument is attached with the cable running lengthwise through it. The cable is deviated or "bent" from its straight course, within the instrument, and the force required to so "bend" it is measured. This force, proportional to tension in cable, is indicated on dial. On hard wire this deviation is influenced by the bending stiffness of the wire itself. However, new instrument incorporates a compensating device which adjusts itself automatically to each size and stiffness of wire measure. Length and shape of new instrument are said to permit a longer length of cable to be measured "than is possible on other types of meter." It has a maximum range of 3,000 lbs. on wire and rope cables up to 7/16" diameter. Instrument is constructed of aluminum alloy and steel, combining lightness and strength, and is said to be "the simplest and most rugged indicator of its kind."—*Goodyear Aircraft Corp., Akron, Ohio.*



Four-way Valves for Hydraulic Servos

New lightweight "Altair" four-way hydraulic selector valves, for 3/8", 1/2" and 3/4" tube size, incorporate self-seating plastic poppets of exclusive design which obviate necessity for inserted seats. These poppets wear "in" instead of "out," can be removed without disassembling connecting lines, are one-sixth the weight of steel, are easily mounted, have withstood 550,000 cycles without exceeding leakage requirements. Cored fluid passages in molded aluminum

alloy body and another feature: oval instead of circular in cross-section, they are said to provide greater flow area, minimizing pressure loss without increasing size and weight of valve. Easy-opening characteristic of ¾" valve results from specially-balanced poppet compensating for increased handle torque. In ½" unit, an alternative valve is available with integral check and relief valves. The latter guards against pressure failures due to thermal expansion by permitting escape of fluid to reservoir when cylinder and its lines form a closed system. A smaller valve for ¼" tube size is also manufactured. New valves are made for operating pressures up to 1500 lbs./in.². They range in weight from 11 oz. for the ¼" to 26 oz. for the ¾".—*Pacific Div., Bendix Aviation Corp., 11600 Sherman Way, North Hollywood, Calif.*

Photoelectric Color Comparators

New Models "400A" and "400G" "Lumetron Colorimeters" are designed for practical colorimetry: are suited for colorimetric and turbidimetric tests in chemical analysis as well as for color matching of liquids.

Both operate with regular full-length test tubes as sample holders. Operation is said to be "so simple and self-explanatory that even the untrained user will master it the very first time." There is no danger of damaging the instrument by faulty operation. Instrument is operated from the power line and is immediately ready for readings. It is standardized by setting the needle on full-scale deflection for the blank which, in most instances, is distilled water. Then, when the blank is replaced by the sample to be tested, the reading of the latter is directly indicated by the needle. Twelve accurately-matched Pyrex test tubes are furnished. Additional matched tubes are available. Or, since test tubes can be purchased at low price from laboratory supply houses, user may select his own matched tubes from a quantity of unmatched tubes. Matching consists in selecting tubes which give the same readings when filled with the same solution. Instrument is designed for test tubes of 18-mm. O.D. but, by removing a Bakelite plate, instrument becomes usable for 22-mm. O.D. tubes. Circuit comprising photocell and indicating instrument is designed to give linear response. Therefore, it is easy to calibrate the instrument for a given determination, straight-line plots being obtained in most tests. Indicating instrument dial carries a transmission scale and a density scale. This makes it possible, in many instances, to get along without graphs or calibration tables. A calibration factor can be determined which, when multiplied with the density reading of the sample, gives the concentration of the unknown directly. The six highly-selective color filters which come with the instrument isolate definite spectral bands without "leakage" at other wave lengths. They appear rather dark to the eye. Their use is made possible by the permits to employ, for special determinations, filters isolating even narrower wavebands than the filters furnished regularly with the instrument. Identical filters are used in "Model 400-A" and "Model 400-G." "Model 400-A" is equipped with an indicating instrument of the jewel-bearing type. It is rapid in action and gives immediate readings. "Model 400-G" is equipped with

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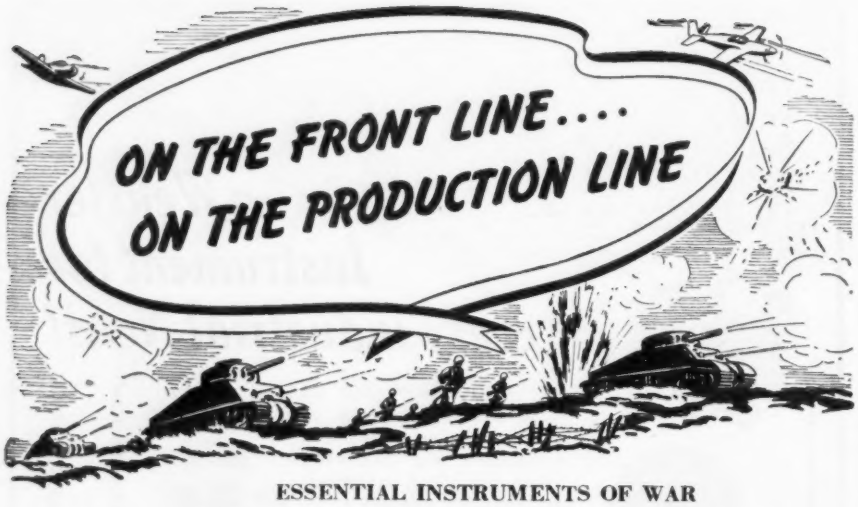

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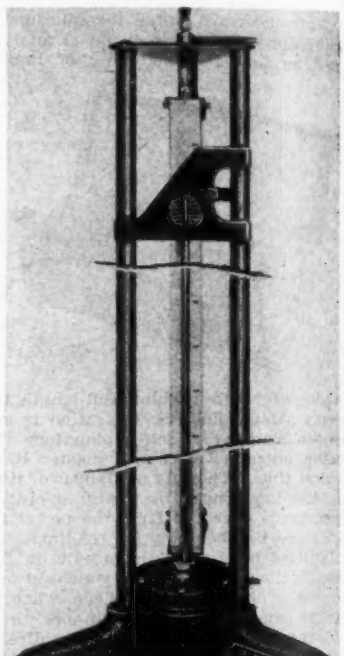
an indicating galvanometer of the taut-wire suspension type, said to be "remarkably rugged and shockproof." Both are practically equivalent in performance, main distinction being that 400-G has a built-in voltage stabilizer, while 400-A has the sliding test tube carrier which is not incorporated in 400-G. In buildings which are subject to appreciable vibrations, 400-A may sometimes be preferable on account of its jewel-bearing indicating instrument. Where the a-c. power line has no controlled frequency or where only direct current is available, 400-G is more suitable because it can be furnished for battery operation.—*Photovolt Corp., 95 Madison Ave., New York City.*

Precision Manometer

New mercurial manometer with several unusual features has a wide variety of uses, functioning equally well as a manometer, barometer, differential pressure in-



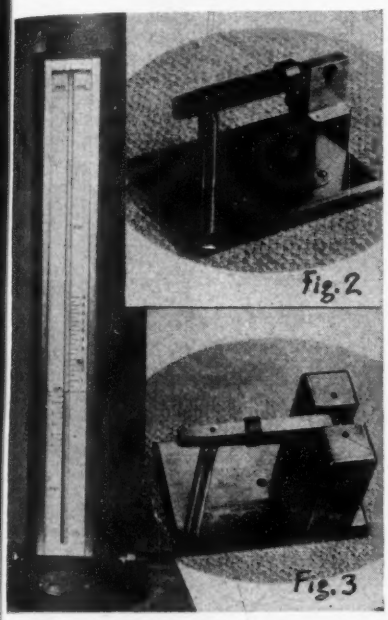
[Two portions suppressed to shorten illustration, which otherwise would be 6½" high.]

dicator and differential vacuum indicator. It is said that ease with which observations can be made gives new manometer special utility in chemical industry. It is especially adapted to checking and calibrating aneroid instruments. Full temperature compensation over any selected range of 30°C. is obtained by setting a graduated knurled nut to the ambient temperature, thus obviating need for applying temperature corrections to scale readings. Another feature is a new type indicator: a thin horizontal steel disk is mounted on top of a stainless steel float which rides on top of the mercury column. Thin edge of disk gives hair-line indication. Readings to nearest 0.1 mm. are made possible by a built-in focusing magnifier which slides vertically on the right-hand supporting column. When used as a barometer, a unique method of sealing the vacuum is employed: level of mercury is raised a short distance above a constriction at upper end of mercury tube; then a stainless steel needle is forced against a ground glass seat, accurately lapped into the constriction. This forms an absolute mercury seal against air leaks and ensuing loss of vacuum. Factory calibration of the scale to compensate for changes in relation between well level and column level makes unnecessary the usual indexing or adjustment for mercury meniscus in the well. Plugs and checks prevent mercury spillage from the well during any normal handling.

although standard calibration is from 0 to 800 mm. of mercury, instrument can be supplied in any other desired calibration such as millibars, inches of mercury, or altitude, either in accordance with Smithsonian Meteorological Table No. 51, or in accordance with U. S. Standard Atmosphere.—*Wallace & Tiernan Products, Inc., Belleville, N. J.*

Air-gage System for Rapidly Gaging to 25 Millionths of Inch

New "Metricator" system embodies unique combination of features said to make possible, at low operating and maintenance costs, the rapid inspection of mass-produced parts to 0.001", to 0.0001" or even to 0.000025" when necessary, as well as other advantages over all solid type gages and over various air-gage systems employing different principles. New system consists essentially of the "Metricator" instrument (Fig. 1) which is



of standard design, and a gaging head designed for the application, such as O.D., I.D., straightness, length, taper, concentricity, etc. "Metricator" instrument regulates air flow and indicates variations. Standard amplification factor is 4000, so that 0.001" is represented by a four-inch length on instrument's scale. Operator fatigue is thereby minimized, because tenthousandths can be read from a distance, and only for reading hundred-thousandths need the operator stand closer than three or four feet. Higher or lower amplifications are available. Air pressure required is approx. 1 lb./in.^{2} and is easily obtained: If plant supply is high-pressure, a line regulator will supply 30 to 50 lbs./in.^{2} and a regulator at instrument will further reduce to desired value. Changes in line pressure cannot affect accuracy of readings because constancy of reference pressure is maintained by keeping water in instrument at proper static level—easily corrected daily by adding water to compensate for evaporation. Principle of measurement is indication of air *flow* between part being gaged and specially-designed measuring orifices. There are two measuring orifices in each gaging head, each recessed with respect to outer skirt of gaging member. Thus, protective skirt can wear considerably before the actual measuring orifices can be affected. Until that point is reached, the initial accuracy is maintained and there is no need for progressive gage wear allowance as in the use of gaging members which make contact. Wear of protective skirt being immaterial up to that point, life of such a gaging head, even in severe service, is many times the life of other types. *Gage Head Forms:* Figs. 2 and 3 are among

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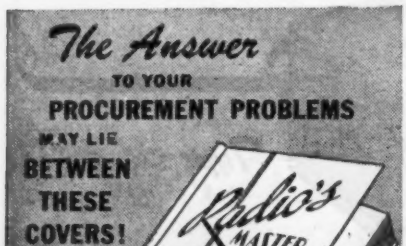

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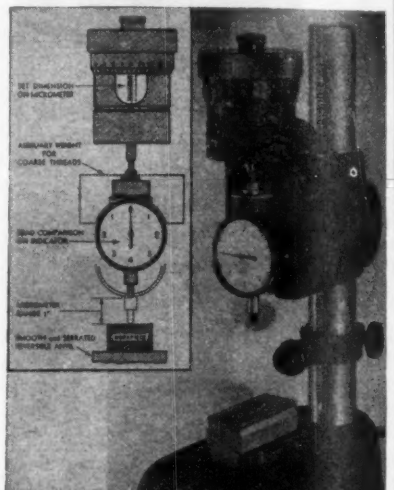
those announced for slots and thicknesses. Numerous other forms are available now, for diameters, tapers, depths, etc., and manufacturers announce early availability of many other standard forms, as well as special shapes as ordered by customers. *Multi-column "Metricators":* These instruments are for simultaneous measurements of several diameters, shoulders, etc.—*Dept. 35, Metrical Laboratories, Inc., 417 Detroit St., Ann Arbor, Mich.*

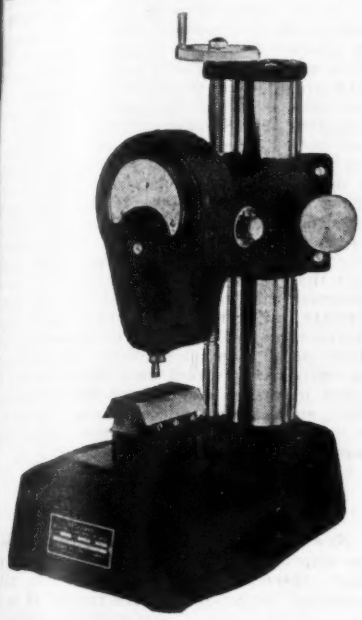
Combination Micrometer and Dial-indicating Comparator

New "Model 120 B-1 Micro-comparator with Micrometer Head and Three-wire Thread Attachments" is a combination instrument of exceptional versatility, useful for production inspection as well as for numerous tool-room uses. Combination micrometer head and dial-indicator comparator provides a convenient instrument for tool rooms and small shops having miscellaneous job lots of duplicate workpieces. The micrometer head takes the place of gage blocks and the dial indicator comparator provides an instrument which is faster than the usual micrometer and is also less subject to human variations. This comparator incorporates its own master: micrometer head obviates need for a complete set of gage blocks for setting dial indicator to required dimension: 1" and 2" gage blocks (furnished as extra) enable user to set gage by means of micrometer to any dimension within 4" vertical capacity. Total capacity is 8". Micrometer head facilitates inspection of thread pitch diameters by three-wire method (usual three-wire formula). An auxiliary weight furnishes additional pressure required for coarser threads. "Federal Super-Sensitive Low Friction Dial Indicator Model D1KB" is graduated in 0.0001". Large diameter of micrometer thimble permits graduations of 0.0001" directly on thimble. Micro-comparator is also used for direct measuring and with a constant contact pressure by setting dial indicator at zero and using that position as a reference. Gaging unit, supported on a rigid 2" column, is quickly positioned by rack-and-pinion and handwheel. A brake prevents the head from dropping. Lateral adjustment or swing of the head makes it possible to set sensitive contact at various positions from edge to edge of anvil as required. Reversible anvil is smooth on one side and serrated on the other. It is ground and lapped flat. Backstop is adjustable for height and also for depth. Maximum throat depth (contact-to-column) is 3⅞". Net weight approx. 62 lb.—*Federal Products Corp., 1144 Eddy St., Providence 1, R. I.*



Multi-range Comparator

New "Electronic Comparator" is for rapid inspection of finished parts on the production line and measurements of mechanical dimensions to extremely close tolerances. It is unusually flexible and versatile because magnification can be varied at will by simple electrical controls: from millionths of an inch to ten-thousandths or to thousandths. Variation in sensitivity (or range) is accomplished by turning a dial through three positive stages of adjustment. Changes in sensitivity do not affect zero adjustment, nor does zero adjustment affect sensitivity. Spindle pressure is instantly adjustable from 0 to 20 ounces. Comparator consists of a rigid stand carrying an anvil, an electric gage head, and an electrical indicating instrument. Electrical zero and magnification adjustments are made by means of convenient controls. Voltage output of electric gage head actuates the indicator. Electric circuit includes compensation for normal voltage and frequency variations so that the instrument may be operated from any 115-volt 60-cycle light socket. Reading is at convenient eye-level. No special skill is required of operator. New instrument is said to be particularly well adapted for use in multiple-gage fixtures where any number of important dimensions may be measured simultaneously.—*Hathaway Instrument Co., Denver 10, Colorado.*



Portable Comparator

New "Precisionometer" is a portable indicating comparator for use by unskilled operators to take measurements said to be of "bench comparator accuracy," without

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New Precision Step Drill Grinder Simplifies Production and Maintenance of Step Drills

The quality of a step drill produced by common methods depends almost entirely on the skill and attention of the individual tool maker. However, with the development of the precision step drill grinder, the human element has been entirely eliminated, the characteristics of the step being completely controlled by the grinding machine without adjustments during the course of grinding. This automatic feature insures absolute uniformity, regardless of quantity, and permits large-volume production of step drills.

The apparent advantages gained through the use of the step drill grinder are: Permits mass production of drills ground to exact specifications, entirely independent of the human element. Maintenance, too, is no longer an obstacle as step drills produced by this method are quickly sharpened by the same uniform machine-controlled operation. With the step drill grinder step drills can now be made from standard drills. These advantages result in a wider application of step drills which provide a definite saving of machine tools, man-hours and cost; this in turn results in greater production.

You know there are plenty of benefits in chewing gum, too. That's why all of the Wrigley's Spearmint we're able to make from our available stocks is going overseas to our fighting men and women. You know what a lift it's been on the job and we wish we could supply everybody, because we have pride, too, in our workmanship and productivity. But there just aren't enough available top quality raw materials right now to do it. When we can produce it in sufficient quantity, it will be back to you with the same fine flavor and chewing satisfaction ...Wrigley's Spearmint has never been changed!

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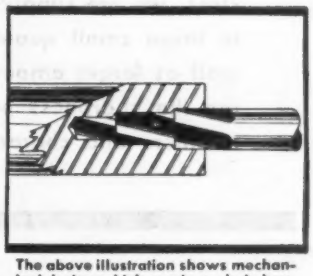

The above illustration shows mechanical design which requires a hole having diameters diminishing in steps. This is an operation for step drills which has often been neglected due to difficulty in obtaining and maintaining step drills.

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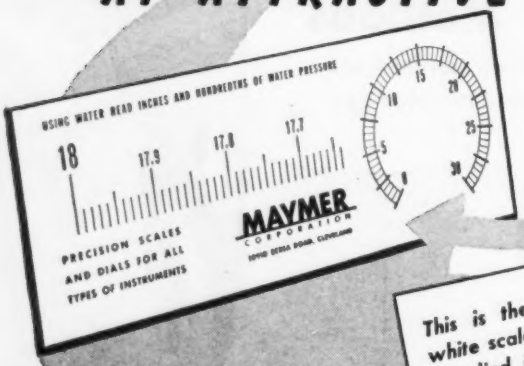

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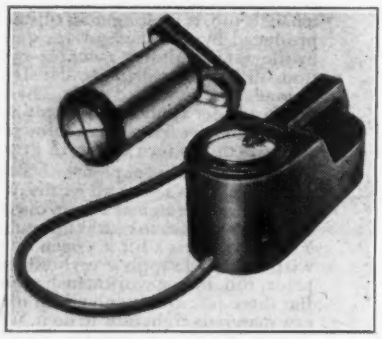

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removing part from machine. It is claimed that in some cases it is not even necessary to stop the machine while measuring. Two models are available having ranges from 1" to 2" and from 2" to 3". Gaging anvil and backstop are faced with sintered carbide. Illustration shows "Model 12," ranging 1" to 2", complete with stand and master. Instrument is "checked each time it is used by placing it in the stand on the master when not in use." There is no sliding friction between moving parts in instrument and provision is made for automatically compensating for temperature changes. It is said that "the only errors of measurement are those of the indicator itself." Indicator is protected from shock, is said to be the finest full-jeweled, low-friction dial indicator commercially available, graduated in ten-thousandths of an inch. "Precisionometer" is said to be lighter and more compact than other portable comparators; is so designed that measurements can be taken directly adjacent to shoulders and other obstructions, and so proportioned that it will clear usual obstacles found on machines. In many cases, direct measurements can be taken in places usually considered inaccessible, such as in undercuts and recesses.—*Bellwether Labs., 7230 Clinton Rd., Upper Darby, Penna.*

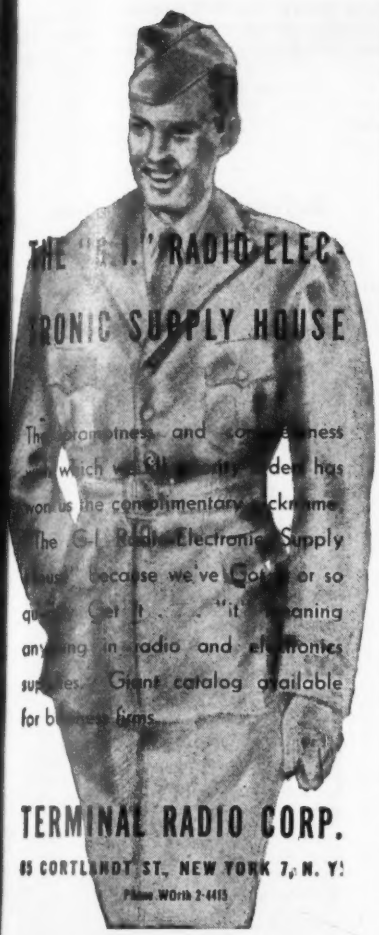
Blue-sensitive Phototube

New "CE-29" blue-sensitive phototube is an improved type, using an octal five-pin base, interchangeable with similar tubes produced by other manufacturers. It is dimensionally similar to the "CE-30" which is said to have become "very popular in industry." With these two tubes, it is possible to convert an equipment from being red-sensitive to blue-sensitive and vice versa by simply interchanging the phototube. "CE-29" is particularly useful with light sources rich in violet, blue, and green light. In many applications it is said, this tube will possess advantages even with light sources which produce considerable red and infra-red light. Though "CE-29" is not sensitive to red and infra-red light, its basic sensitivity on an energy basis is at least ten times that of conventional red-sensitive phototubes. RMA spectral sensitivity designation is S-4. Several other types with different dimensions will be available in the near future.—*Continental Electric Company, Geneva, Illinois.*

Optical Flats

New "DoALL" optical flats are claimed to possess greater wearability and lower coefficient of expansion. They are made from fused Brazilian quartz which has a Mohs

hardness of seven as compared with six for optical grade glass. Having a much lower coefficient of expansion than optical glass, they are said to remain flat after considerable handling. Six sizes in diameters of 2", 3", 4", 5", 6", and 10" are available, each in a hardwood case. "DoALL" optical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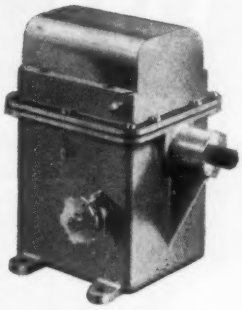

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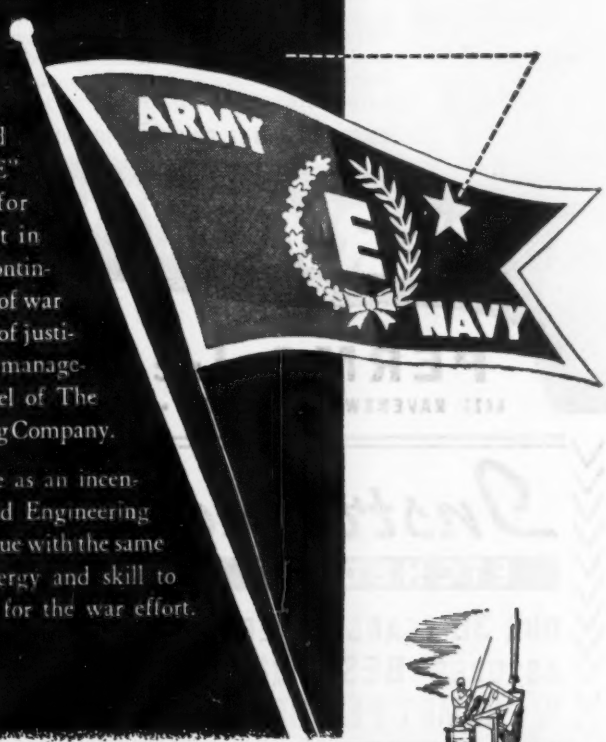

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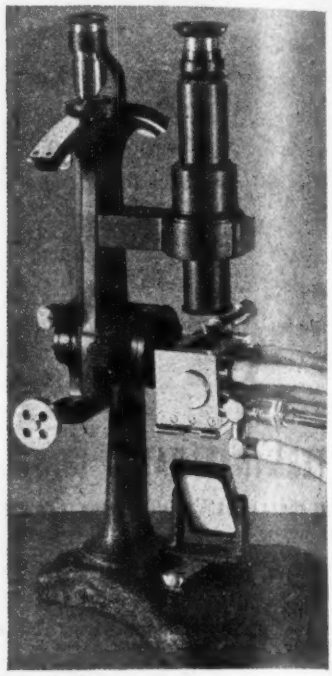
"New Model Spencer Refractometer" is an Abbe type instrument but has no Amici compensating prisms. It is used with monochromatic light and provides an ex



tremely sharp dividing line which facilitate accurate setting of the arm. Three model are available. One has scale graduated refractive index from 1.3 to 1.71 and num bered so that it can be read from either side. Second, covering same range, has combination scale which reads directly percent of sugar in solution as well as r fractive index. Third has special high inde scale covering range of 1.45 to 1.84. Scale read percent of sugar or refractive inde directly when a sodium vapor lamp is use with refractometer (special correctio charts supplied on request for use with mercury vapor lamp or hydrogen discharg tube as light source). Little material needed to obtain reading and results a obtained immediately.—*Spencer Lens Co 19 Doat St., Buffalo 11, N. Y.*

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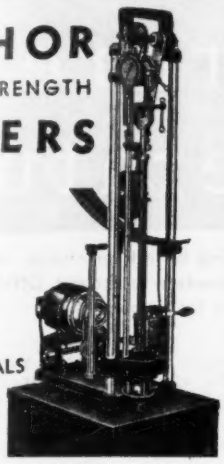

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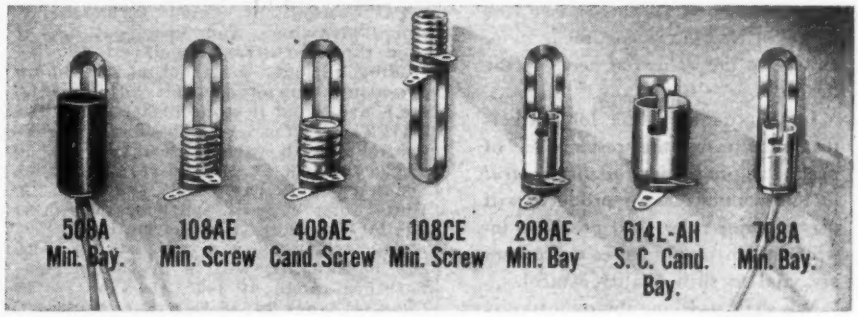

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Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. To assist in the War Effort we urge readers to request ONLY those bulletins which will be of value to them. Use the coupon on the facing page.

L-118 **Solderless Wiring Devices.** Catalog SD-1, 8¼" × 10¾", 72 pages. Wire terminals, and related tools for installation, which eliminate necessity of solder connections. Complete specifications for standard, flag type and insulation support wire terminals. All types fully illustrated by drawings and photographs for clarity and easy interpretation of data. Similar information included for cable lugs, bonding jumpers and bonding tabs. Numerous pages are devoted to useful reference data such as stud size selector chart, stud hole standards, etc. Aircraft-Marine Products Inc., 1523 N. Fourth St., Harrisburg, Pa.

L-119 **Granite Surface Plates.** Folder, 8½" × 11", 4 pages. Precision surface plates for accurate measurements. Plates 18" × 24" can be finished to an accuracy of 0.00005"; and plates as large as 4' × 6' have been held to a tolerance of 0.0003" overall. Standard stock plates described are held to a tolerance of 0.0001" overall. Contents point out that these plates are non-warping, durable, non-abrasive, non-magnetic, temperature-resistant, rust-proof and corrosion-proof. Plates are illustrated by photographs. Price list included. Herman Stone Co., 324 Harries Bldg., Dayton 2, Ohio.

L-120 **Thermal Controls.** Catalog, 9¼" × 11½", 6 pages. Thermostats for electrical control of temperature. Dimensional drawings and specifications of each type are given. Specifications, (including ratings, construction, maximum operating temperatures, adjustments, etc.), are listed in appropriate tables for quick selection. Assembled units are available with various ratings from 50 to 2000 watts at 115-230-volt a. c., depending upon particular type chosen. Units for "built-in" purposes are also available with ratings normally of 1500 watts at 115v-230-v. a. c. Nearly all units can be supplied with a maximum temperature range of 300°, 450°, or 700°F. George Ulanet Co., 88 East Kinney Street, Newark, N. J.

L-121 **New Parts Publication.** Leaflets GEG-3750 to GEG-3758 incl., 8½" × 11", 1 page each. Data for easy identification of parts used in DW-51 d.c. voltmeters (1 to 300-volt max. and 500 to 750-volt self-contained); DW-51 d-c. ammeters, milliammeters, and microammeters; DW-52 r-f. ammeters and milliammeters (self-contained and external 'couple type); DW-53 d-c. voltmeters (30 to 150 volts); DW-53 d-c. volt-ammeters; and, DW-53 d-c. ammeters and milliammeters. Each leaflet has a photograph showing an "exploded" instrument — with parts, numbered and identified, in their normal relationship to one another when assembled. General Electric Co., News Bureau, Schenectady, N. Y.

L-122 **General Radio Experimenter.** February issue, 6" × 9", 8 pages. Features an article on speed control of repulsion and series motors, induction motors, split-phase motors, repulsion-start induction motors, and capacitor and capacitor-start motors by means of the Variac. Also contains Part II of "Continuous Interpolation Methods." General Radio Company, 30 State Street, Cambridge 39, Mass.

L-123 **Motor Valves.** Bulletin #60[illegible] 8½" × 11", 8 pages. Motor valves for regulation of gas or liquid flow to or from a controlled system. A pilot instrument, responding to pressure changes in the system, supplies a variable pressure to the motor valve for controlled operation. Descriptions and specifications, supplemented by drawings and photographs explain the application and features of the various types of units available. Wilgus Mfg. Co., 1722 East 16th St., Los Angeles, Cal.

L-124 **Pressure Relief Valves.** Bulletin 8½" × 11", 1 page. Designed to meet aircraft requirements, these valves can be easily adjusted with ordinary pliers or wrench without being removed from the line. Additional features are fully explained in the text which is illustrated by a cross-sectional view of a typical unit. Rogers Products Inc., 3711 Hudson Blvd., Jersey City, N. J.

L-125 **Double Flaring Tool for Plastic Tubing.** Bulletin Form 388, 8½" × 11", 1 page. A tool for making approved-type flares on ⅜", ½", ⅝", and ¾" O. D. plastic tubing, with .062" wall. Complete kit, contained in a metal box, consists of a steel flaring bar, a forged steel yoke with swivel cone, and four adapters. Can be easily carried around and used "on the job". The tool and accessories are fully illustrated by photographs. Imperial Brass Mfg. Co., 1200 West Harrison Street, Chicago, Ill.

L-126 **Radius Charts, Protractor Charts, Projector Scales, & Projector Rules.** Bulletin 1-44ER, 8½" × 11", 20 pages. For use with optical comparators and measuring and micro projectors. Most of these charts have an O. D. of 14½" and are composed of fine black lines and easily read numerals on a finely ground surface of selected plate glass. Various scales are available for use at different magnifications such as 10X, 20X, 31.25X, etc. There are numerous photographs illustrating the many charts that are available. Projector rules and scales, accessories to increase the usefulness of these charts and the projectors, are also included in this publication. The Universal Engraving and Colorplate Company, Inc., Engineer's Specialties Div., 588 Monroe St., Buffalo 11, N. Y.

L-127 **Synthetic Optical Crystals.** Booklet, 8½" × 11", 16 pages. Commercial production of synthetic crystals grown from molten salts of lithium fluoride, sodium chloride, and potassium bromide. The infrared range up to 25 microns can be effectively covered by these optics, it is stated. Characteristics of each salt crystal are given in detail in the text, and several pages are devoted to an explanation of their application in infrared spectroscopy. Numerous photographs illustrate the text, and show in detail the manufacturing process of a synthetic crystal. Harshaw Chemical Co., 1945 East 97th Street, Cleveland 6, Ohio.

L-128 **Aircraft Fire Detectors.** Circular, 8½" × 11", 8 pages. Two types of detectors specifically designed for aircraft application. The continuous type detector, available in lengths up to 7.5 ft, consists of a copper wire suitably housed in, and insulated from, a copper-plated tin alloy tubeshell. The tin-alloy has a melting point of 350°F, and a fire will cause this alloy to melt thus making electrical contact between the internal copper wire and the external copper plating. This contact causes a warning signal in the cockpit to warn the pilot that emergency action must be taken. The unit type detector consists of a specially designed thermoswitch and is used where the continuous type of detector is not feasible. Complete specifications and descriptions, with applicable drawings, photographs, and wiring diagrams are included in this publication. Fenwal Inc., Ashland, Mass.

L-129 **Capacitors.** Folder, 8½" × 11", 4 pages. Specifications for hermetically sealed—oil impregnated—oil filled A-N type bathtub condensers; oil filled—oil impregnated capacitors; and, mica condensers. Numerous types are available for immediate shipment from a limited stock supply. Photographs are used to illustrate each of the above types. Sprague Products Co., North Adams, Mass.

L-130 **Allied News.** Bulletin (March issue), 8½" × 11", 4 pages. Contains various articles and news items about equipment and developments in the electronic field. Allied Radio Corp., 833 West Jackson Blvd., Chicago, Ill.

L-131 **Aircraft Servo Control Systems.** Folder, 8½" × 11", 4 pages. Design Check Chart #4 which includes specifications, design features, and illustrations of motors specifically designed to control aircraft flight operations. Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.

L-132 **Apparatus for Preparing Metallurgical Specimens.** Folder, 8½" × 11", 2 pages. Explains "3-step" technique for comparatively rapid preparation of metallurgical specimens with (1) specimen cutter, (2) mounting press, and (3) automatic polisher. All three units are illustrated. Precision Scientific Co., 1736 N. Springfield Ave., Chicago, Ill.

L-133 **Cam Timers.** Bulletin, 8½" × 11", 4 pages. For accurately controlling the sequence and duration of a series of three or more individually timed machine or process operations. These units are of standard parts construction which provides flexibility of design to meet special requirements without difficulty. The operating principle is illustrated by drawings, and detailed features of design are illustrated and explained. Automatic Temperature Control Co., Inc., 34 E. Logan St., Philadelphia, Pa.

L-134 **Electric Starters for Aircraft.** Folder, 8½" × 11", 4 pages. Design Check Chart #5 for "Series 43" inertia and direct cranking electric starters (AAF Types G-5, G-6, H-5 and H-6). Wiring diagrams and photographs are used to illustrate the text. Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.

L-135 **Pressure Loaded Reducing Regulators.** Bulletin 514A, 8½" × 11", 4 pages. For reducing gas pressures where the service is severe and fluctuating. The valve action of these regulators is actuated by air or gas pressure which may be controlled remotely or at the regulator. Text explains principle of operation and diagrammatic drawings, including photographs, illustrate the proper installation and operation of these units. The standard units are designed for maintaining regulated pressure from one to 150 lbs. per square inch, but other ranges are available. Specifications and price lists are included in this publication. Natural Gas Equipment Inc., Petroleum Securities Bldg., Los Angeles, Cal.

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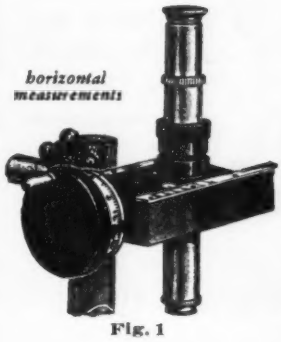

Fig. 1

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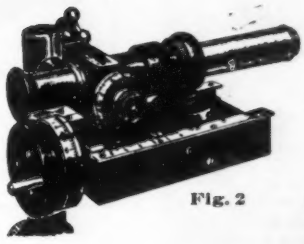

Fig. 2

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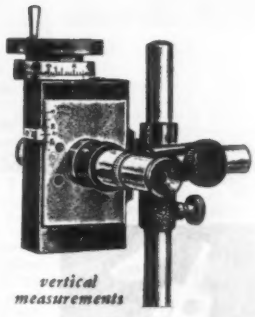

Fig. 3

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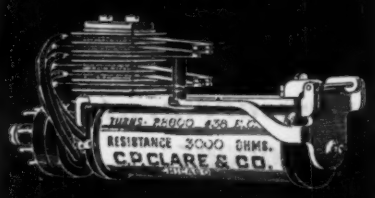

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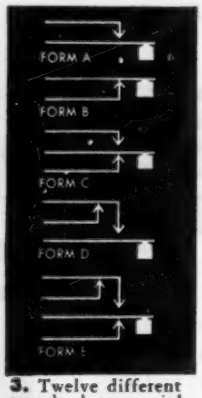

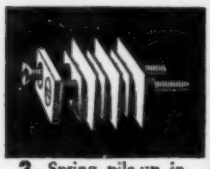

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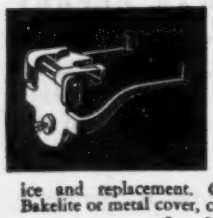

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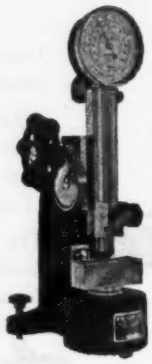

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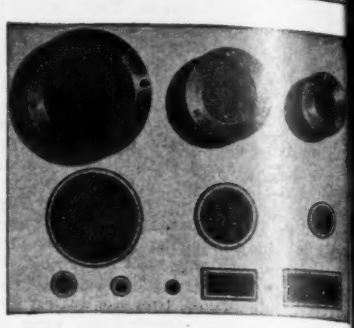

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